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THE MINERAL METABOLISM OF THE MILCH COW

SECOND PAPER

OHIO Agricultural Experiment Station

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BULLETIN
OF THE
Ohio Agricultural Experiment Station

NUMBER 308 JANUARY, 1917

THE MINERAL METABOLISM OF THE MILCH COW

SECOND PAPER

E. B. FORBES, F. M. BEEGLE, C. M. FRITZ, L. E. MORGAN AND S. N. RHUE

No human food is more nearly indispensable than is cow's milk. It is important, therefore, to know all the facts regarding the physiology of milk production, regardless of present economic bearings.

As we have previously observed, the milch cow is remarkable, among farm animals, for the rapidity with which she produces proteid and mineral nutriment in her milk, the unusual protein requirement of the cow being fully understood, but her mineral requirements having received scant recognition.

Our first study of the mineral metabolism of the milch cow[1] established facts of consequence which, previously, had hardly been suspected. It had been our belief that all animals which receive leafy forage as a considerable part of the ration consume and digest as much of the mineral nutrients as required by maximum functional activities. The prevalence of this belief among practical and scientific students of animal production appears scarcely to have been affected by the existence in the literature of pathology of many hundreds of reports of malnutrition of the bones of just such animals. This malady has been considered as due to very unusual conditions of feeding; and its common occurrence has not been generally understood to have a significant bearing on normal practice in milk production.

The most important result of our earlier study of this subject was a demonstration of the fact that ordinarily liberal milk production, on common practical winter rations, fed in quantities sufficient to maintain the live weight and to cause regular protein storage, involves consistent losses of calcium, magnesium and phosphorus

[1] Ohio Agr. Exp. Sta. Bul. 295, The Mineral Metabolism of the Milch Cow (1916).

from the cows' skeletons. This conclusion was based on 18 agreeing balances of income and outgo. Changes in the rations, which served greatly to increase the intake of these elements, caused but slight reduction of the losses from the body. An especially limited utilization of the minerals, on the plane of profitable milk production, thus became apparent.

OBJECTS OF THE EXPERIMENT

The objects of our second study, therefore, were to learn whether mineral equilibrium can be maintained on rations containing the maximum amounts of mineral nutriment obtainable in common practical feeds, and to determine the effects of large additions to these rations of calcium, magnesium and phosphorus in supplemental form, as inorganic salts; also to ascertain the reason for the limited utilization of the mineral nutrients during ordinarily liberal food consumption.

METHOD OF EXPERIMENTATION

The method of this study, as of the preceding one, involved the complete chemical accounting for food, milk, urine and feces. Details of procedure were as in the published report of the earlier work. Six Holstein cows were used, in collection periods of 20 days, separated by 10-day intervals on the ration of the collection period to follow. The cows were all in their second, third or fourth period of lactation. None were bred during this experiment. Had they been bred, according to the usual practice, mineral requirements would have been increased, and negative mineral balances, in all probability, would also have been more extensive. They were fed and milked four times daily, at 6-hour intervals. There was no refused feed to analyze. The milk yield varied from 38.7 to 58.35 pounds per head and day, with an average production of 47.15 pounds. The conduct of this experiment required full time from 17 men, in addition to the general oversight of the head of the department.

RATIONS

In order to attain the desired ends—maximum contents of calcium, magnesium and phosphorus—all rations were based on a leguminous roughage (either clover or alfalfa hay), corn silage, cottonseed meal, linseed oilmeal and wheat bran, all of which are rich in mineral nutriment. Cornmeal was used as the principal source of carbohydrate, but contributed comparatively little mineral substance.

In Period I, Cows 2, 3 and 4 received alfalfa hay; the others, clover. Otherwise the rations were compounded from the same feeds. In Period II, Cows 2, 3 and 4 were given a double allowance of salt, with the idea in mind that deficiency of salt in the rations of the year before might possibly have restricted the digestion of calcium, magnesium and phosphorus by limiting the supply of hydrochloric acid in the gastric juice. In this period the rations were further varied by giving calcium carbonate to Cows 5 and 6, and bone flour to Cows 1 and 4. This bone flour, which was supplied by Hirsch, Stein & Company of Chicago, is the bone-dust formed during the grinding of bones into meal for fertilizing purposes. The fat is previously extracted from the bones with naphtha, and the nitrogenous substance is removed by alternate steam digestion and hot-water treatments.

RESULTS OF THE EXPERIMENT

Table I, page 463, exhibits the average daily amounts of foods consumed, and of milk produced; also the live weights of the cows. The milk production was high, for common cows. The cows were comparatively small for Holsteins. They weighed from 1,167 to 890 pounds at the beginning of the experiment. During the course of the investigation the cows gained in weight in six cases and lost in weight the same number of times, the losses slightly exceeding the gains.

Table II, page 464, sets forth the analyses of the feeds. Among the notable details of composition are the very high calcium contents of the clover and alfalfa hay, the low calcium content of the corn, the high silicon content of the linseed oilmeal, and the high sodium and chlorine contents of the alfalfa.

Table III, page 465, shows that there were no noticeable effects of the foodstuffs or mineral supplements (sodium chloride, calcium carbonate and bone flour) on the composition of the milk.

Table IV, page 466, records the amounts of the daily rations. The food consumption was maintained without change, from day to day, during each collection period; and all foods weighed to the cows were eaten without waste. As is usual in such experiments it was necessary to depart, in certain particulars, from our plan of feeding, in order to maintain the cooperation of some of the cows. Cow No. 2 demanded especial consideration in the composition of her ration. It was necessary to feed this cow a much larger proportion of roughage to concentrates than was given to other individuals. This fact accounts for the high mineral content of the rations fed to Cow 2.

Tables V, VI and VII, on pages 467 to 469, record the amounts of the constituents in the average daily milk, urine and feces.

Tables VIII and IX, pages 470 and 471, set forth the balances of the mineral nutrients and of nitrogen. As is indicated by the headings of the columns, the groups of figures within the squares signify (reading downward) food, milk, urine and feces. The fourth column of the tables states the characteristic or distinguishing features of the somewhat complicated rations.

The intake of sodium and of chlorine was prominently affected by the alfalfa hay, which was rich in these elements, and also by the amount of common salt fed. Salt was allowed in the amount of 28 grams per head and day, except in Period II, when Cows 2, 3 and 4 received double the usual amount, that is, 56 grams.

In Period I, Cows 2, 3 and 4 received from 20.077 to 25.638 grams of sodium per day, and stored from 4.254 to 9.140 grams per day, of this element. In Period II, with an intake of sodium about 50 percent greater than in Period I, two of these cows lost sodium while the other one gained but a very small amount. Cows 2 and 4, which had stored the most sodium in Period I, lost sodium in Period II; while Cow 3, which stored the least in Period I, gained a very little in Period II.

These data show that the sodium intake of Cows 2, 3 and 4 in Period I was more than sufficient, and that in Period II it was excessive, the negative balances representing not deficiency but the throwing off of previously absorbed stores.

With a sodium intake of between 12 and 13 grams per day, in both periods, Cows 1, 5 and 6 retained sodium in three cases and lost sodium in three others, the gains very slightly exceeding the losses.

We may say, then, from the results with Cows 1, 5 and 6 in the two periods, that with cows producing about 45 pounds of milk daily, 28 grams (one ounce) of salt per head daily adds just about enough sodium to rations of ordinary feeds to provide for sodium equilibrium, though Cows 2, 3 and 4 retained considerable amounts of sodium when only one ounce of salt was fed per day, since these cows received alfalfa hay, which was very much richer in sodium than was the clover hay fed to Cows 1, 5 and 6 in both periods.

The feeding of 56 grams (two ounces) of salt per day to Cows 2, 3 and 4 in Period II, tells us nothing about sodium requirements, since it happened that these cows had stored sodium in abundance in the previous period when only 28 grams of salt was fed.

In gauging the salt fed according to the milk produced, we may consider that 10 grams of salt contains as much sodium as 25 pounds

of milk, and that an ounce of salt contains as much sodium as 70 pounds of milk. An allowance of one to two ounces of salt per day, in accord with the amount of milk produced will cover all sodium requirements.

In connection with the sodium balances we naturally consider those of chlorine, since sodium and chlorine are taken in the food mostly combined as common salt. Nine of the twelve chlorine balances are negative. Even with an intake of 82.335 grams of chlorine per day, Cow 2 excreted 3.229 grams more of chlorine than she received. These negative chlorine balances cannot signify insufficiency, since the balances were always negative during heaviest consumption of chlorine, and since the three positive balances occurred during the intake of minimum amounts. We seem at all times to have had present in the rations an abundance of chlorine.

Many uncertainties in the interpretation of mineral metabolism data are due to the fact that either positive or negative balances may signify only comparatively unimportant fluctuations in extensive reserves. We do not always have at hand evidence to determine whether a negative balance indicates insufficient intake or merely the throwing off of useless stores in the face of excessive supplies—all of which is equivalent to saying that our balance periods, even the longest of them, are much too short for the most satisfactory study of mineral metabolism.

The potassium balances were positive in all cases but one. The retention varied greatly, in one case (Cow 2, Period II) being 26.837 grams per day. This maximum potassium retention was associated with maximum potassium intake, very largely as contributed by the alfalfa hay in the ration. Apparently enough potassium was present in the rations at all times. The data do not afford us evidence as to just how much potassium is required.

Among the most significant results from this investigation are the balance data relating to calcium, magnesium and phosphorus. As in the previous year's work, all calcium balances were negative, and all magnesium balances but one were negative. In Period I the phosphorus balances were all negative, but in Period II the increased phosphorus intake resulted in all positive balances. With regard to this most important group of mineral nutrients, then, the results are satisfactorily regular and accountable.

In interpreting the uniformly negative calcium balances we might consider them as due possibly (1) to insufficient intake, (2) to the retention being limited by deficiency in the available amounts of the magnesium and phosphorus with which calcium would be

combined in storage in the skeleton, and without which calcium cannot be stored in any considerable quantity in any organ or tissue, or (3) to some factor which limits absorption of calcium.

The limited response of the cow to great increase in calcium intake shows that it was not a deficiency of calcium in the ration which caused the negative calcium balances; further, on account of the very high intake of magnesium, it is impossible to consider that this element limited the retention of calcium; and since, in Period II, all phosphorus balances were positive, while the calcium balances remained negative, it is impossible that deficiency of this element should account for the negative calcium balances. The inference, therefore, becomes unmistakable that the cause of the negative calcium balances is some factor which limits calcium absorption, the probability being that the deficient utilization of magnesium and phosphorus is due to the same agency.

We are then confronted with the question, What is this agency and why are these elements so imperfectly absorbed?

In seeking for that condition essential to the appropriation of these nutrients, which limits their utilization by its inadequacy, we have considered the acidity of the gastric juice. If an insufficient supply of hydrochloric acid in the gastric juice restricts the digestion of calcium, magnesium and phosphorus, the administration of these nutrients in water-soluble form, or other forms not requiring the agency of hydrochloric acid to bring them into solution, would shed light on this question. This point will be studied in a later experiment.

Whatever the facts regarding this matter, the formation of the hydrochloric acid of the gastric juice seems not to have been maintained below normal by the sodium chloride intake in the majority of these rations, since doubling the allowance of common salt produced no noticeable change in the utilization of those mineral nutrients which require hydrochloric acid for their digestion.

The nitrogen and sulphur balances measure the protein metabolism. In our earlier study the signs of the nitrogen and sulphur balances (+ or —) were the same in 16 cases out of 18, and in this later investigation they were the same in 9 cases out of 12. The extent of the gains and losses of these elements show that, in general, the cows were maintained in a condition not far from equilibrium, which, for our purpose, signifies that the cows were neither stuffed nor starved; that is, our data and conclusions have to do with cows in a normal state of nutrition.

Table X, pages 472 and 473, contains the amounts of feeds consumed and of milk produced, in pounds; also (in grams) the daily intake and balance of the mineral nutrients and of nitrogen. This table is presented simply as a convenient summary.

Table XI, page 474, records the mineral constituents of the rations expressed as cubic centimeters of the elements. The column at the right shows that the bases exceeded the acids by considerable amounts in all cases, even with the total silicon included. A part of this silicon must have been present as a contamination of soil, and would not enter into metabolic processes. Such variations in balance of base and acid as exist in these rations appear not to affect the retention of the mineral elements.

Table XII records data on the utilization and elimination of nitrogen. The amount of ammonia nitrogen in the urine is very small (0.23-0.76 gm. daily); the elimination of acids in combination with ammonia in the urine (as in omnivora and carnivora) is therefore inconsiderable in extent in cows on such rations as were used in this experiment. Even in the previous study, where (in rations containing timothy hay) the acids exceeded the bases, the urinary ammonia, though slightly increased, remained a very small proportion of the total urinary nitrogen.

The three columns at the right of the table represent the percentage distribution of nitrogen among urine, feces and utilization, the utilized nitrogen being the nitrogen of the milk plus positive (or minus negative) nitrogen balances.

These figures show a marked difference in the proportion of the food nitrogen which is eliminated in the urine, as affected by the kind of hay consumed, there being (on an average) about 27 percent of the nitrogen from the alfalfa rations, and 19 percent of the nitrogen from the clover rations, eliminated in the urine. The proportions of nitrogen in the feces from the alfalfa and the clover hay rations show that the greater proportion of the nitrogen of the alfalfa rations which was excreted in the urine depended upon more complete absorption from the intestine; but the percentage of utilization of nitrogen in the two groups of rations was about the same. It would seem, therefore, that the greater digestibility of the nitrogen compounds of alfalfa does not signify corresponding nutritive superiority.

Table XIII, page 476, sets forth the digestion coefficients of the rations. The only noteworthy differences in digestibility were those just mentioned as due to the effects of the two kinds of hay consumed. In this connection we would call attention to the nutritive

ratios of the several rations (column at right of table). We have not data at hand to warrant an opinion as to how much the differences in nutritive ratio of the rations affected the digestibility of the protein. It is a fact not without bearing on this matter, however, that the protein of alfalfa hay is reported in the literature as being more digestible than the protein of clover hay.

In the computation of the protein digestion coefficients correction was made for metabolic nitrogen, which was estimated by the pepsin-hydrochloric acid method.

In accounting for the products from the metabolism of the food, by analysis of milk and excreta, it becomes apparent that there is much variability in the paths of outgo of the mineral nutrients; that is, a given element may be eliminated largely or wholly in the urine, under some circumstances, or, under other conditions, it may be excreted as largely in the feces.

From the point of view of the student of metabolism this great variability in the paths of elimination of the body wastes signifies that it is never safe to draw conclusions from the analysis of urine or feces alone. Both paths of outgo must be considered.

This variability in methods of elimination of wastes also calls our attention to the fact, which is overlooked with discouraging frequency, that we cannot assume that because a nutrient compound appears in the feces, it has escaped absorption. We cannot determine digestion coefficients for ash or for ash constituents, because we cannot distinguish between undissolved constituents and those which have been digested, and after participation in body metabolism, have been reexcreted into the intestine.

A further observation which should be made, relative to the significance of urine and feces analyses, is that the various circumstances which determine the path of outgo of absorbed nutrients are commonly without correspondingly important bearing on the retention of these elements by the body.

In the publication of the results of our first study of the mineral metabolism of the milch cow, we made no attempt to account for the observed variations in the paths of outgo of the mineral nutrients. With the additional evidence derived from the second experiment at hand it now becomes possible more satisfactorily to attempt such deductions. We are recording data on this matter from our second experiment, therefore, in Table XIV, pages 477 and 478, and from the earlier work in Tables XV, XVI and XVII on pages 479 to 481.

A prominent variation is to be noted in the proportionate elimination of sodium and chlorine in the urine and feces. In some cases nearly all the sodium of the excreta was in the urine, while in others it was nearly all in the feces. The same may be said of chlorine. The variations in elimination of sodium and of chlorine in urine and feces are usually roughly parallel, and may be considered as due largely to the amount taken in the food and to varying thoroughness of absorption, as influenced by the length of time the food remains in the digestive tract. High intake of sodium and chlorine increases the outgo of these elements in both urine and feces, but increases the outgo in the urine more than in the feces, thus decreasing the proportionate outgo in the feces. Among those circumstances which tend to increase the proportionate elimination of sodium and of chlorine in the urine are high intake of these elements, constipation, and, as observed in our work with swine,[1] high water intake.

As also observed, first in our work with swine, though sodium and chlorine are usually consumed largely together as sodium chloride, still there is a considerable measure of independence in the metabolism of these elements, because they function to a large extent in different combinations and in different physiological processes.

The path of elimination of potassium is most largely controlled by other influences than those affecting sodium and chlorine. Among the 30 balances involved in this consideration there was a much larger proportionate excretion of potassium in the urine than in the feces in 27 cases. In the other three cases, where the elimination in the feces exceeded that in the urine, the ration fed differed from those in the 27 cases by being rich in silicon and poor in calcium, through the use of timothy instead of clover or alfalfa hay, these differences resulting in a prominent excess of acid to basic minerals in the ration.

Calcium was always very low in the urine, but was slightly higher in the three cases where timothy hay was fed and where an excess of mineral acid to base prevailed.

Magnesium was always contained in much greater quantity in the urine than was calcium. The urine usually contained about one-fourth as much magnesium as did the feces.

The excretion of phosphorus was much like that of calcium. Extremely little was usually present in the urine, though the amount

[1]Ohio Agr. Exp. Sta. Bul. 271, A Chemical Study of the Nutrition of Swine (1914).

was slightly increased by the mineral acidity of the ration containing timothy hay. Unlike calcium, however, the urinary phosphorus was sometimes much increased (as in the case of Cow 4, Tables XV, XVI and XVII) by general physiologic disturbance.

Sulphur was usually excreted in the urine in quantities from one-third to one-fourth as great as in the feces. Certain feeds, however, through their high sulphur content, had the effect to increase this proportion in the urine in prominent ways; thus in the work of 1915 (Table XVII, page 481) gluten feed had the effect to increase the proportion of urinary to feces sulphur to more than one-half; and the work of 1916 (Table XIV, pages 477 and 478) showed that alfalfa hay has a marked tendency to increase urinary sulphur. This is especially noticeable with Cow 2, which consumed more alfalfa hay than did other cows. This individual excreted as much sulphur in the urine as in the feces. These variations seem to be consistently related to the intake of sulphur.

SUMMARY

The prevailing belief that all animals which receive leafy forage as a considerable part of the ration consume and digest an abundance of mineral nutriment is shown not to be true, in relation to cows, during ordinarily liberal milk production.

With rations of common practical foods, especially chosen to provide maximum supplies of the mineral nutrients, all calcium, magnesium and phosphorus balances were negative, as in the previous year's work.

With large increases in the calcium, magnesium and phosphorus contents of these rations, through increased amounts of food consumed and through the addition to the rations of large amounts of calcium carbonate and bone flour, all calcium balances and all but one magnesium balance remained negative, but the phosphorus balances became positive.

This work presents satisfactory evidence that in the selective improvement of milch cows we encounter limited capacities to digest calcium, magnesium and phosphorus, and inability to maintain their body stores of these elements before any such limitations are apparent in their ability to digest and to utilize the organic nutrients.

We suggest a restricted capacity for the formation of hydrochloric acid as possibly one of the limiting factors in the utilization of the calcium, magnesium and phosphorus of common foods and of mineral supplements.

Doubling the usual sodium chloride allowance did not improve the retention of calcium, magnesium and phosphorus.

Twenty-eight grams (one ounce) of salt per head and day, with a ration of common foods, provides enough sodium for cows producing 45 pounds of milk per day. An allowance of one to two ounces of salt per head and day, in accord with the amount of milk produced, will cover all sodium requirements.

Rations containing enough sodium to meet the cow's needs commonly contain a larger proportionate supply of chlorine.

Enough potassium seems to have been supplied by all the rations studied. A deficiency of potassium in normal rations, therefore, seems unlikely.

The various circumstances which determine the path of outgo of absorbed nutrients are commonly without corresponding effect on the retention of these elements in the body.

In some cases nearly all the sodium of the excreta was in the urine, while in others it was nearly all in the feces. The same may be said of chlorine.

The elimination of sodium and chlorine in the urine is increased by high intake of these elements, by constipation and by high water intake.

Potassium in cows is commonly excreted in much larger proportion in the urine than in the feces, but in rations characterized by predominance of acid minerals, potassium was eliminated more largely in the feces.

Calcium is excreted by cows almost wholly in the feces, but a predominance of acid minerals in the ration may cause slight increase in urinary calcium.

Magnesium always exceeds calcium in the urine, but is contained in the feces in amounts usually about four times as great as in the urine.

The excretion of phosphorus is characterized by much the same proportionate distribution as the excretion of calcium, except that urinary phosphorus may be much increased by general physiologic disturbance.

Sulphur is normally excreted in the feces, in quantities three or four times as great as in the urine, but with high sulphur intake the urinary sulphur may equal the feces sulphur.

There were no noticeable effects of the foodstuffs or the mineral supplements (sodium chloride, calcium carbonate or bone flour) on the amount or composition of the milk.

Such variations in the balance of acid and basic mineral elements as occur in normal cow rations do not affect the retention of the mineral elements in unmistakable ways.

Evidence was obtained showing that negative balances of the mineral nutrients may signify either deficient intake of the same, or the throwing off of previously absorbed stores, in the face of continued superabundant supplies. Either positive or negative balances may signify, under certain circumstances, only comparatively unimportant fluctuations in extensive reserves.

The nitrogen compounds of rations containing alfalfa hay are more digestible than the nitrogen compounds of rations containing clover hay; they are more completely absorbed from the intestine, but are more largely eliminated in the urine. The greater digestibility of the alfalfa nitrogen, therefore, seems not to signify corresponding nutritive superiority. The percentages of utilization of the nitrogen compounds of rations containing clover and of those containing alfalfa were the same.

The deficient utilization of the minerals by cows, as we have demonstrated the facts, has practical bearings in the malnutrition of the bones of cattle, which is not uncommon after seasons of drouth, and overstocking of pastures, particularly in regions of unfertile, sandy, soils or soils of granitic origin, especially if these be worn through long cropping with deficient fertilization; further practical bearings are probably seen in the rather common failure of cows to breed after a season of forced milk production; also in the failure of many cows fed for high production to maintain high records during consecutive periods of lactation; perhaps also as a contributory cause in the usual shrinkage of milk flow, with advance in the period of lactation.

The most important single result from these studies is that, thus far, under no circumstances, have we been able to cause calcium storage or to maintain calcium equilibrium. That the cow does maintain calcium equilibrium during less abundant milk production may be considered an unproved certainty, though we do not know how much less abundant the production must be in order that the cow may be able to maintain calcium equilibrium.

Among the important factors of this problem which are yet to be investigated are the following:

(1) At what time, and under what conditions of feeding, lactation or reproductive activity does a cow make good the mineral losses sustained during heavy milk production?

(2) Can these losses be prevented, and if so in what manner?

(3) What advantages would accrue to the cow from removing the necessity of her drawing upon her skeleton for a part of the mineral requirements of milk production?

TABLE I.—AVERAGE DAILY FOODS CONSUMED AND MILK PRODUCED; AND LIVE WEIGHTS OF COWS (Kilograms)

Cow No., and days in period		Foods consumed										Milk produced	Weight of cows	
		Corn	Cotton-seed meal	Wheat bran	Linseed oilmeal	Clover hay	Alfalfa hay	Corn silage	Salt	Bone flour	Calcium carbonate		Average first five daily weights	Average last five daily weights
PERIOD I														
2	8	3.5190	0.4692	0.4692	0.2346	.....	5.456	13.636	0.0280	.....	.....	23.622	480.48	475.00
3	14	3.7017	.4936	.4936	.2468	.....	3.180	11.940	.0280	.....	.....	23.640	404.58	400.30
4	14	4.0920	.5456	.5456	.2728	.....	3.636	11.360	.0280	.....	.....	20.528	432.40	440.04
1	20	4.0920	.5456	.5456	.2728	4.544	.....	13.636	.0284	.....	.....	17.560	530.24	533.02
5	20	4.0920	.5456	.5456	.2728	4.544	.....	13.636	.0280	.....	.....	18.779	458.28	451.18
6	20	4.0920	.5456	.5456	.2728	4.544	.....	13.636	.0280	.....	.....	20.012	508.08	508.24
PERIOD II														
2	20	4.0920	.5456	.5456	.2728	.....	7.272	15.908	.0560	.....	.....	26.468	484.12	486.98
3	20	4.4320	.5904	.5904	.2952	.....	3.636	13.636	.0560	.....	.....	23.117	398.80	392.04
4	20	4.0920	.5456	.5456	.2728	.....	4.544	12.728	.0560	0.070	.....	21.875	447.52	446.36
1	20	4.0920	.5456	.5456	.2728	4.544	.....	14.544	.0280	.070	.....	20.224	529.20	511.30
5	20	4.7720	.6368	.6368	.3184	4.544	.....	15.452	.0280	.....	0.070	20.413	460.62	462.08
6	20	4.0920	.5456	.5456	.2728	4.544	.....	14.544	.0280	.....	.070	20.441	513.24	516.64

TABLE II.—COMPOSITION OF FOODS (Percent)

Food	Dry matter	Ether extract	Crude fiber	Nitrogen	Protein	Nitrogen-free extract	Ash	Sodium	Potassium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus	Silicon
PERIOD I															
Corn	86.55	3.8787	2.420	1.3590	8.4938	70.4025	1.3550	None	0.3514	0.0137	0.1143	0.1227	0.0170	0.2794	0.0130
Cottonseed meal	92.31	6.6733	12.087	5.5314	34.5713	32.9964	5.9820	0.0638	1.4805	0.2031	0.5836	0.3920	0.0151	1.0921	0.0052
Linseed meal	91.86	6.7920	7.563	5.5304	34.5650	36.4560	6.4840	0.0939	1.1801	0.3841	0.5334	0.3757	0.0145	0.7847	0.3492
Wheat bran	89.47	4.1625	8.440	2.7680	17.3000	53.6065	5.9610	0.0790	1.2610	0.1006	0.5161	0.2043	0.0265	1.0198	0.0296
Corn silage (Cows 1, 2, 5 and 6)	28.80	0.8749	6.770	0.3571	2.2319	17.5568	1.3664	None	0.2572	0.0634	0.0496	0.0336	0.0250	0.0520	0.2100
Corn silage (Cows 3 and 4)	28.59	0.9439	6.526	0.3789	2.3681	17.3612	1.3908	0.0023	0.2620	0.0629	0.0533	0.0351	0.0263	0.0544	0.2435
Clover hay	88.16	2.3413	30.409	1.6525	10.3280	38.3435	6.7382	0.0141	1.7393	1.0351	0.2802	0.1153	0.0590	0.1218	0.1933
Alfalfa (Cow 2)	90.61	2.2783	28.490	2.4207	15.1296	35.6920	9.0201	0.2533	2.3023	1.3345	0.2324	0.3306	0.5645	0.1690	0.1690
Alfalfa (Cows 3 and 4)	89.32	2.2457	28.083	2.3861	14.9130	35.1873	8.8910	0.2496	2.2693	1.3153	0.2291	0.3258	0.5564	0.1666	0.1367
PERIOD II															
Corn	87.13	3.8400	2.207	1.4160	8.8500	70.9150	1.3180	None	0.3571	0.0111	0.1181	0.1236	0.0205	0.2721	0.0094
Cottonseed meal	92.81	7.8160	10.377	6.1440	38.4000	30.1100	6.1070	0.0673	1.4894	0.2112	0.5999	0.4270	0.0110	1.1318	0.0028
Linseed meal	92.02	6.8960	7.697	5.4300	33.9375	37.0575	6.4320	0.0829	1.1773	0.3953	0.5385	0.3868	0.0129	0.7837	0.3942
Wheat bran	90.33	4.2080	8.765	2.6715	16.6969	54.7141	5.9460	0.0842	1.2417	0.1107	0.5391	0.2211	0.0221	1.3354	0.0324
Corn silage	27.37	0.7678	6.373	0.3650	2.2813	16.2671	1.6808	None	0.3369	0.0625	0.0610	0.0394	0.0317	0.0617	0.3124
Clover hay	93.62	2.4864	32.294	1.7549	10.9681	40.7157	7.1558	0.0150	1.8471	1.0992	0.2975	0.1225	0.0626	0.1294	0.2053
Alfalfa	91.76	2.1495	30.904	2.1940	13.7125	36.0455	8.9485	0.2039	2.6208	1.2572	0.2344	0.3063	0.5850	0.1804	0.0875
Calcium carbonate	99.87	.....	.....	.....	.....	.....	97.4500	.....	0.1544	32.0740	0.2283	0.0808	0.0035	0.0000	.....
Bone flour	97.50	2.6360	.....	1.1638	7.2738	.....	83.0400	.....	0.2220	29.5294	0.6275	0.4548	0.1362	13.4225	.....

Composition of salt: Na=39.028; Cl=60.172.

TABLE III.—COMPOSITION OF MILK (Percent)

Cow No.	Moisture	Nitrogen	Protein (N x 6.37)	Ether extract	Ash	Sodium	Potassium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus
PERIOD I												
2	89.21	0.4145	2.6404	2.872	0.741	0.0411	0.1882	0.0991	0.0107	0.0271	0.1209	0.0816
3	88.12	.3627	2.3104	3.994	.697	.0353	.1689	.0971	.0128	.0265	.0922	.0813
4	88.56	.3523	2.2442	2.907	.670	.0311	.1576	.1037	.0105	.0245	.0842	.0726
1	88.14	.4942	3.1481	2.853	.757	.0398	.1657	.1282	.0113	.0309	.0806	.0866
5	89.27	.3630	2.3123	2.766	.668	.0298	.1689	.1012	.0091	.0211	.0830	.0798
6	88.10	.4347	2.7690	3.229	.730	.0298	.1657	.1241	.0109	.0269	.0732	.0787
PERIOD II												
2	89.80	.3848	2.4512	3.028	.708	.0392	.1906	.0804	.0106	.0251	.1193	.0691
3	88.84	.3884	2.4741	3.269	.665	.0356	.1727	.0840	.0122	.0248	.0981	.0642
4	88.80	.3945	2.5130	2.880	.661	.0298	.1599	.1014	.0097	.0249	.0820	.0718
1	88.87	.4077	2.5970	3.270	.669	.0434	.1559	.0942	.0109	.0260	.0924	.0781
5	89.20	.4063	2.5881	2.686	.716	.0298	.1708	.1081	.0096	.0232	.0792	.0899
6	88.58	.4177	2.6607	3.143	.723	.0330	.1657	.1129	.0100	.0250	.0735	.0825

TABLE IV.—CONSTITUENTS OF DAILY RATIONS (Grams)

Cow No.	Dry matter	Ether extract	Crude fiber	Nitrogen	Protein	Nitrogen-free extract	Sodium	Potassium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus	Silicon
PERIOD I														
2	12984.961	446.871	2676.786	280.504	1753.180	7310.732	25.638	188.684	84.263	29.876	30.617	51.883	37.894	39.296
3	10581.819	397.941	1881.810	226.040	1412.742	6315.417	20.077	132.899	52.292	24.624	22.963	38.553	34.498	34.936
4	11279.510	425.247	1994.106	245.780	1536.122	6704.469	21.299	144.831	58.235	26.517	25.133	41.030	37.334	34.306
1	12717.169	462.056	2536.596	239.762	1498.515	7589.201	12.740	146.662	58.946	31.627	19.121	24.112	37.722	39.094
5	12717.169	462.056	2536.596	239.762	1498.515	7589.201	12.604	146.662	58.946	31.627	19.121	23.901	37.722	39.094
6	12717.169	462.056	2536.596	239.762	1498.515	7589.201	12.604	146.662	58.946	31.627	19.121	23.901	37.722	39.094
PERIOD II														
2	15842.409	520.002	3476.902	338.466	2115.414	8674.734	37.736	276.905	104.655	39.266	38.191	82.335	49.667	57.712
3	12283.070	444.389	2226.242	260.378	1627.373	7281.944	30.409	176.658	57.795	30.390	26.956	60.432	43.910	47.570
4	12537.080	438.792	2431.179	267.821	1673.884	7174.119	32.173	194.851	68.370	30.931	28.900	65.463	52.179	45.390
1	13050.388	466.199	2610.074	253.683	1585.514	7681.743	12.662	165.657	62.326	34.906	20.945	25.358	41.587	56.416
5	14170.285	513.393	2703.917	277.141	1732.132	8405.927	12.839	174.279	85.897	37.708	22.968	25.823	46.605	59.529
6	13120.297	466.199	2610.074	253.683	1585.514	7681.743	12.662	165.765	84.778	35.066	21.002	25.360	41.587	56.416

TABLE V.—CONSTITUENTS OF AVERAGE DAILY MILK (Grams)

Cow No.	Nitrogen	Ether extract	Ash	Sodium	Potassium	Calcium	Magnesium	Sulphur	Phosphorus	Chlorine
PERIOD I										
2	97.9111	678.4095	175.0353	9.7084	44.4557	23.4089	2.5275	6.4014	19.2752	28.5584
3	85.9757	946.7520	165.2194	8.3676	40.0367	23.0169	3.0342	6.2817	19.2716	21.8554
4	72.3159	596.7137	137.5295	6.3838	32.3502	21.2863	2.1553	5.0291	14.9025	17.2836
1	87.0294	502.4176	133.3088	7.0088	29.1800	22.5762	1.9899	5.2870	14.8174	14.1938
5	68.1683	519.4313	125.4447	5.5962	31.7180	19.0045	1.7089	3.9624	14.9858	15.5867
6	86.9885	646.1600	146.0814	5.9633	33.1585	24.8338	2.1812	5.3830	15.7488	14.6482
PERIOD II										
2	102.3889	805.7008	188.3871	10.4305	50.7155	21.3931	2.8205	6.6787	18.3864	31.7438
3	89.7882	755.7094	153.7310	8.2298	39.9238	19.4187	2.8203	5.7331	14.8414	22.6782
4	86.2766	629.8517	144.5597	6.5172	34.9699	22.1760	2.1214	5.4456	15.7026	17.9333
1	82.4508	661.3052	135.2945	8.7770	31.5283	19.0504	2.2044	5.2581	15.7945	18.6864
5	83.1674	549.8094	146.5613	6.0999	34.9618	22.1275	1.9651	4.7489	18.4020	16.2118
6	85.3814	642.4559	147.7873	6.7455	33.8705	23.0777	2.0441	5.1102	16.8637	15.0240

TABLE VI.—CONSTITUENTS OF AVERAGE DAILY URINE (Grams)

Cow No.	Nitrogen	Sodium	Potassium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus
PERIOD I								
2	81.0495	6.3938	114.1110	0.8743	4.7105	12.4388	18.5163	0.1302
3	49.6328	4.8237	67.4443	0.3851	3.7044	6.4814	10.8514	.1147
4	66.1871	0.2753	87.6052	0.5781	6.6311	8.7837	12.0062	.1763
1	49.0082	0.6673	61.3712	2.5431	7.8062	3.1542	3.4299	.1228
5	45.4869	0.4200	75.0580	0.0884	3.6996	2.9376	0.2015	.1205
6	38.0211	0.6622	68.7589	0.4136	4.2148	2.4160	0.1920	.1040
PERIOD II								
2	103.8532	18.9274	165.0598	0.3881	4.9387	15.5892	36.1458	.1262
3	61.4052	10.0257	97.0465	0.2683	5.6697	8.9556	28.5460	.1185
4	76.8859	10.9434	117.3832	0.4834	7.5302	10.9031	26.9248	.1504
1	54.3890	1.0189	86.7638	0.1738	7.4494	3.6990	0.4812	.1644
5	48.9173	4.5754	98.1876	0.0706	5.0251	3.3989	0.2562	.1163
6	43.3547	1.0834	104.3216	0.3346	4.5982	3.1447	0.2828	.1035

TABLE VII.—CONSTITUENTS OF AVERAGE DAILY FECES (Grams)

Cow No.	Total weight	Dry matter	Ether extract	Crude fiber	Nitrogen	Protein	Metabolic nitrogen	Indigestible nitrogen	Nitrogen-free extract	Sodium	Potassium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus
PERIOD I																
2	30,447	4204.7825	158.6613	1369.7361	110.3413	689.6328	52.7348	57.6064	1595.5036	0.3958	24.6319	67.9585	25.3931	12.3616	12.1790	22.2875
3	23,914	3694.7461	118.8536	982.0133	92.1415	575.8839	47.0153	45.1261	1732.9378	2.6306	18.3900	40.1520	19.9205	9.7331	8.3461	19.8727
4	23,880	3617.8092	126.5397	937.7887	100.2718	626.7009	53.2045	47.0673	1608.9380	8.2625	28.3455	41.8854	19.6771	10.4594	14.3996	23.8561
1	30,124	4473.3472	123.0547	1285.1610	112.0897	700.5594	51.2100	60.8797	1994.9561	1.9580	53.7705	41.1789	24.9423	10.8144	8.2237	26.8100
5	31,080	4658.8545	146.4789	1362.8781	119.7503	748.4406	52.0586	67.6917	2021.5732	7.0551	35.6485	46.5885	29.3393	10.8468	7.2105	24.9260
6	31,363	4709.2657	128.4545	1308.6867	120.3967	752.4781	53.9590	66.4376	2156.5751	2.3201	36.9028	41.2609	27.5595	10.4720	7.1172	24.0793
PERIOD II																
2	40,631	5407.9196	186.2908	1595.4378	140.4190	877.6188	57.8578	82.5612	2222.0008	9.8732	34.2921	88.1276	33.1139	16.0897	17.6743	25.7597
3	29,342	4342.6604	131.1894	1131.1163	109.3001	683.1250	46.3022	62.9979	2038.6667	11.4142	25.2050	44.7470	24.0607	12.1771	10.9740	26.0560
4	27,596	3984.8335	136.2405	1226.9921	102.8495	642.8094	42.8011	60.0485	1555.1961	15.8124	25.2226	68.3548	23.0425	11.7282	21.2488	33.9704
1	32,264	4707.2811	110.2130	1346.2695	116.8593	730.3719	36.5548	80.3045	2039.0516	8.2595	42.3300	66.4633	27.8759	11.9053	8.8725	31.9734
5	36 327	5216.4926	150.9005	1403.5126	132.0833	825.5219	58.5947	73.4886	2367.9451	4.7225	30.0421	70.1829	32.2217	12.2784	7.8465	24.0845
6	33 880	4797.4222	104.6218	1293.7794	113.3967	708.7281	44.8573	68.5394	1755.2724	2.7443	20.7007	68.5733	28.1544	11.2821	10.3334	23.9194

TABLE VIII.—PERIOD I: AVERAGE DAILY RATIONS, AND BALANCES OF MINERALS AND NITROGEN (Grams)

Cow No.	Ave. daily milk yield	Average daily ration	Distinguishing features of rations		Sodium	Potassium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus	Nitrogen
2	23,622	Corn, 3519; cottonseed meal, 469.2; wheat bran, 469.2; linseed meal, 234.6; corn silage, 13636; alfalfa hay, 5456; salt, 28	Alfalfa hay	Food	25.638	188.684	84.263	29.876	30.617	51.883	37.894	280.504
				Milk	9.708	44.456	23.409	2.528	6.401	28.558	19.275	97.911
				Urine	6.394	114.111	0.874	4.711	12.439	18.516	0.130	81.050
				Feces	0.396	24.632	67.959	25.393	12.362	12.179	22.288	110.341
				Balance	+ 9.140	+ 5.485	— 7.979	— 2.756	— 0.585	— 7.370	— 3.799	— 8.798
3	23,640	Corn, 3701.7; cottonseed meal, 493.6; wheat bran, 493.6; linseed meal, 246.8; corn silage, 11940; alfalfa hay, 3180; salt, 28	"	Food	20.077	132.899	52.292	24.624	22.963	38.553	34.498	226.040
				Milk	8.368	40.037	23.017	3.034	6.282	21.855	19.272	85.976
				Urine	4.824	67.444	0.385	3.704	6.481	10.851	0.115	49.633
				Feces	2.631	18.390	40 152	19.921	9.733	8.346	19.873	92.142
				Balance	+ 4.254	+ 7.028	—11.262	— 2.035	+ 0.467	— 2.499	— 4.762	— 1.711
4	20,528	Corn, 4092; cottonseed meal, 545.6; wheat bran, 545.6; linseed meal, 272.8; corn silage, 11360; alfalfa hay, 3636; salt, 28	"	Food	21.299	144.831	58.235	26.517	25.133	41.030	37.334	245.780
				Milk	6.384	32.350	21.286	2.155	5.029	17.284	14.903	72.316
				Urine	0.275	87.605	0.578	6.631	8.784	12.006	0.176	66.187
				Feces	8.263	28.346	41.885	19.677	10.459	14.400	23.856	100.272
				Balance	+ 6.377	— 3.470	— 5.514	— 1.946	+ 0.861	— 2.660	— 1.601	+ 7.005
1	17,560	Corn, 4092; cottonseed meal, 545.6; wheat bran, 545.6; linseed meal, 272.8; corn silage, 13636; clover hay 4544; salt, 28.35	Clover hay	Food	12.740	146.662	58.946	31.627	19.121	24.112	37.722	239.762
				Milk	7.009	29.180	22.576	1.990	5.287	14.194	14.817	87.029
				Urine	0.667	61.371	2.543	7.806	3.154	3.430	0.123	49.008
				Feces	1.958	53.771	41.179	24.942	10.814	8.224	26.810	112.090
				Balance	+ 3.106	+ 2.340	— 7.352	— 3.111	— 0.134	— 1.736	— 4.028	— 8.365
5	18,779	Corn, 4092; cottonseed meal, 545.6; wheat bran, 545.6; linseed meal, 272.8; corn silage, 13636; clover hay, 4544; salt, 28	"	Food	12.604	146.662	58.946	31.627	19.121	23.901	37.722	239.762
				Milk	5.596	31.718	19.005	1.709	3.962	15.587	14.986	68.168
				Urine	0.420	75.058	0.088	3.700	2.938	0.202	0.121	45.487
				Feces	7.055	35.649	46.589	29.339	10.847	7.211	24.926	119.750
				Balance	— 0.467	+ 4.237	— 6.736	— 3.121	+ 1.374	+ 0.901	— 2.311	+ 6.357
6	20,012	Corn, 4092; cottonseed meal, 545.6; wheat bran, 545.6; linseed meal, 272.8; corn silage, 13636; clover hay, 4544; salt, 28	"	Food	12.604	146.662	58.946	31.627	19.121	23.901	37.722	239.762
				Milk	5.963	33.159	24.834	2.181	5.383	14.648	15.749	86.989
				Urine	0.662	68.759	0.414	4.215	2.416	0.192	0.104	38.021
				Feces	2.320	36.903	41.261	27.560	10.472	7.117	24.079	120.397
				Balance	+ 3.659	+ 7.841	— 7.563	— 2.329	+ 0.850	+ 1.944	— 2.210	— 5.645

TABLE IX.—PERIOD II: AVERAGE DAILY RATIONS, AND BALANCES OF MINERALS AND NITROGEN (Grams)

Cow No.	Ave. daily milk yield	Average daily ration	Distinguishing features of rations		Sodium	Potassium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus	Nitrogen
					Food	Food	Food	Food	Food	Food	Food	Food
					Milk	Milk	Milk	Milk	Milk	Milk	Milk	Milk
					Urine	Urine	Urine	Urine	Urine	Urine	Urine	Urine
					Feces	Feces	Feces	Feces	Feces	Feces	Feces	Feces
					Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance
2	26,468	Corn, 4092; cottonseed meal, 545.6; wheat bran, 545.6; linseed meal, 272.8; corn silage, 15908; alfalfa hay, 7272; salt, 56	Alfalfa hay	Salt, 56 grams	37.736 10.431 18.927 9.873 − 1.495	276.905 50.716 165.060 34.292 + 26.837	104.655 21.393 0.388 88.128 − 5.254	39.266 2.821 4.939 33.114 − 1.608	38.191 6.679 15.589 16.090 − 0.167	82.335 31.744 36.146 17.674 − 3.229	49.667 18.386 0.126 25.760 + 5.395	338.466 102.389 103.853 140.419 − 8.195
3	23,117	Corn, 4432; cottonseed meal, 590.4; wheat bran, 590.4; linseed meal, 295.2; corn silage, 13636; alfalfa hay, 3636; salt, 56	Alfalfa hay	"	30.409 8.230 10.026 11.414 + 0.739	176.658 39 924 97.047 25.205 + 14.482	57.795 19.419 0.268 44.747 − 6.639	30.390 2.820 5.670 24.061 − 2.161	26.956 5.733 8.956 12.177 + 0.090	60.432 22.678 28.546 10.974 − 1.766	43.910 14.841 0.119 26.056 + 2.894	260.378 89.788 61.405 109.300 − 0.115
4	21,875	Corn, 4092; cottonseed meal, 545.6; wheat bran, 545.6; linseed meal, 272.8; corn silage, 12728; alfalfa hay, 4544; salt, 56; bone flour, 70	Alfalfa hay; bone flour	"	32.173 6.517 10.943 15.812 − 1.099	194.851 34.970 117.383 25.223 + 17.275	89.041 22.176 0.483 68.355 − 1.973	31.370 2.121 7.530 23.043 − 1.324	28.900 5.446 10.903 11.728 + 0.823	65.463 17.933 26.925 21.249 − 0.644	52.179 15.703 0.150 33.970 + 2.356	267.821 86.277 76.886 102.850 + 1.808
1	20,224	Corn, 4092; cottonseed meal, 545.6; wheat bran, 545.6; linseed meal, 272.8; corn silage, 14544; clover hay, 4644; salt, 28; bone flour, 70	Clover hay; bone flour	Salt, 28 grams	12.662 8.777 1.019 8.260 − 5.394	165.812 31.528 86.764 42.330 + 5.190	82.997 19.050 0.174 66.463 − 2.690	35.345 2.204 7.449 27.876 − 2.184	21.263 5.258 3.699 11.905 + 0.401	25.453 18.686 0.481 8.873 − 2.587	50.983 15.795 0.164 31.973 + 3.051	254.498 82.451 54.389 116.859 + 0.799
5	20,413	Corn, 4772; cottonseed meal, 636.8; wheat bran, 636.8; linseed meal, 318.4; corn silage, 15452; clover hay, 4544; salt, 28; calcium carbonate, 70	Clover hay; calcium carbonate	"	12.839 6.100 4.575 4.723 − 2.559	174.279 34.962 98.188 30.042 + 11.087	85.897 22.128 0.071 70.183 − 6.485	37.708 1.965 5.025 32.222 − 1.504	22.968 4.749 3.399 12.278 + 2.542	25.823 16.212 0.256 7.847 + 1.508	46.605 18.402 0.116 24.085 + 4.002	277.141 83.167 48.917 132.083 + 12.974
6	20 441	Corn, 4092; cottonseed meal, 545.6; wheat bran, 545.6; linseed meal, 272.8; corn silage, 14544; clover hay, 4544; salt, 28; calcium carbonate, 70	Clover hay; calcium carbonate	"	12.662 6.746 1.083 2.744 + 2.089	165.765 33.871 104.322 20.701 + 6.871	84.778 23.078 0.335 68.573 − 7.208	35.066 2.044 4.598 28.154 + 0.270	21.002 5.110 3.145 11.282 + 1.465	25.360 15.024 0.283 10.333 − 0.280	41.587 16.864 0.104 23.919 + 0.700	253.683 85.381 43.355 113.397 + 11.550

TABLE X.—AVERAGE DAILY FEED, MILK AND BALANCE DATA FROM SIX COWS—Continued

Cow No.	Rations (Pounds)	Distinguishing features of rations	Milk yield	Gain or loss to the body (Grams)							
				Sodium	Potassium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus	Nitrogen
				Intake Balance	Intake Balance	Intake Balance	Intake Balance	Intake Balance	Intake Balance	Intake Balance	Intake Balance
PERIOD I			*Lb.*								
2	Corn, 7.758; cottonseed meal, 1.034; wheat bran, 1.034; linseed meal, 0.517; corn silage, 30.062; alfalfa hay, 12.028 salt, 0.062	Alfalfa hay	52.077	25.638 + 9.140	188.684 + 5.485	84.263 — 7.979	29.876 — 2.756	30.617 — 0.585	51.883 — 7.370	37.894 — 3.799	280.504 — 8.798
3	Corn, 8.161; cottonseed meal, 1.088; wheat bran, 1.088; linseed meal, 0.544; corn silage, 26.323; alfalfa hay, 7.011; salt, 0.062	" "	52.116	20.077 + 4.254	132.899 + 7.028	52.292 —11.262	24.624 — 2.035	22.963 + 0.467	38.553 — 2.499	34.498 — 4.762	226.040 — 1.711
4	Corn, 9.021; cottonseed meal, 1.203; wheat bran, 1.203; linseed meal, 0.601; corn silage, 25.044; alfalfa hay, 8.016; salt, 0.062	" "	45.256	21.299 + 6.377	144.831 — 3.470	58.235 — 5.514	26.517 — 1.946	25.133 + 0.861	41.030 — 2.660	37.334 — 1.601	245.780 + 7.005
1	Corn, 9.021; cottonseed meal, 1.203; wheat bran, 1.203; linseed meal, 0.601; corn silage, 30.062; clover hay, 10.018; salt, 0.063	Clover hay	38.713	12.740 + 3.106	146.662 + 2.340	58.946 — 7.352	31.627 — 3.111	19.121 — 0.134	24.112 — 1.736	37.722 — 4.028	239.762 — 8.365
5	Corn, 9.021; cottonseed meal, 1.203; wheat bran, 1.203; linseed meal, 0.601; corn silage, 30.062; clover hay, 10.018; salt, 0.062	" "	41.400	12.604 — 0.467	146.662 + 4.237	58.946 — 6.736	31.627 — 3.121	19.121 + 1.374	23.901 + 0.901	37.722 — 2.311	239.762 + 6.357
6	Corn, 9.021; cottonseed meal, 1.203; wheat bran, 1.203; linseed meal, 0.601; corn silage, 30.062; clover hay, 10.018; salt, 0.062	" "	44.118	12.604 + 3.659	146.662 + 7.841	58.946 — 7.563	31.627 — 2.329	19.121 + 0.850	23.901 + 1.944	37.722 — 2.210	239.762 — 5.645

TABLE X.—AVERAGE DAILY FEED, MILK AND BALANCE DATA FROM SIX COWS—Concluded

Cow No.	Rations (Pounds)	Distinguishing features of rations		Milk yield	Gain or loss to the body (Grams)							
					Sodium	Potassium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus	Nitrogen
					Intake Balance	Intake Balance	Intake Balance	Intake Balance	Intake Balance	Intake Balance	Intake Balance	Intake Balance
PERIOD II				*Lb.*								
2	Corn, 9.021; cottonseed meal, 1.203; wheat bran, 1.203; linseed meal, 0.601; corn silage, 35.071; alfalfa hay, 16.032; salt, 0.123	Alfalfa hay	Salt, 56 grams	58.351	37.736 − 1.495	276.905 + 26.837	104.655 − 5.254	39.266 − 1.608	38.191 − 0.167	82.335 − 3.229	49.667 + 5.395	338.466 − 8.195
3	Corn, 9.771; cottonseed meal, 1.302; wheat bran, 1.302; linseed meal, 0.651; corn silage, 30.062; alfalfa hay, 8.016; salt, 0.123	Alfalfa hay	"	50.963	30.409 + 0.739	176.658 + 14.482	57.795 − 6.639	30.360 − 2.161	26.956 + 0.090	60.432 − 1.766	43.910 + 2.894	260.378 − 0.115
4	Corn, 9.021; cottonseed meal, 1.203; wheat bran, 1.203; linseed meal, 0.601; corn silage, 28.060; alfalfa hay, 10.018; salt, 0.123; bone flour, 0.154	Alfalfa hay; bone flour	"	48.225	32.173 − 1.099	194.851 + 17.275	89.041 − 1.973	31.370 − 1.324	28.900 + 0.823	65.463 − 0.644	52.179 + 2.356	267.821 + 1.808
1	Corn, 9.021; cottonseed meal, 1.203; wheat bran, 1.203; linseed meal, 0601; corn silage, 32.063; clover hay, 10.018 salt, 0.062; bone flour, 0.154	Clover hay; bone flour	Salt, 28 grams	44.586	12.662 − 5.394	165.812 + 5.190	82.997 − 2.690	35.345 − 2.184	21.263 + 0.401	25.453 − 2.587	50.983 + 3.051	254.498 + 0.799
5	Corn, 10.520; cottonseed meal, 1.404; wheat bran, 1.404; linseed meal, 0.702; corn silage, 34.065; clover hay, 10.018; salt, 0.062; calcium carbonate, 0.154	Clover hay; calcium carbonate	"	45.002	12.839 − 2.559	174.279 + 11.087	85.897 − 6.485	37.708 − 1.504	22.968 + 2.542	25.823 + 1.508	46.605 + 4.002	277.141 + 12.974
6	Corn, 9.021; cottonseed meal, 1.203; wheat bran, 1.203; linseed meal, 0.601; corn silage, 32.063; clover hay, 10.018; salt, 0.062; calcium carbonate, 0.154	Clover hay; calcium carbonate	"	45.064	12.662 + 2.089	165.765 + 6.871	84.778 − 7.208	35.066 + 0.270	21.002 + 1.465	25.360 − 0.280	41.587 + 0.700	253.683 + 11.550

TABLE XI.—MINERALS IN DAILY RATIONS COMPUTED TO NORMAL SOLUTIONS (Cubic Centimeters)

Cow No.	Sodium	Potassium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus	Silicon	Total base	Total acid	Excess base
PERIOD I											
2	1115	4826	4206	2457	1909	1463	2442	2777	12604	8591	4013
3	873	3399	2610	2025	1432	1087	2223	2469	8907	7211	1696
4	926	3704	2907	2181	1567	1157	2406	2424	9718	7554	2164
1	554	3751	2942	2601	1192	680	2431	2763	9848	7066	2782
5	548	3751	2942	2601	1192	674	2431	2763	9842	7060	2782
6	548	3751	2942	2601	1192	674	2431	2763	9842	7060	2782
PERIOD II											
2	1641	7082	5224	3229	2382	2322	3200	4079	17176	11983	5193
3	1322	4518	2885	2499	1681	1704	2829	3362	11224	9576	1648
4	1399	4983	3413	2544	1802	1846	3362	3208	12339	10218	2121
1	551	4237	3111	2871	1306	715	2680	3987	10770	8688	2082
5	558	4457	4287	3101	1432	728	3003	4207	12403	9370	3033
6	551	4240	4231	2884	1310	715	2680	3987	11906	8692	3214

TABLE XII.—UTILIZATION AND ELIMINATION OF NITROGEN

Cow No.	Distinguishing features of rations		Nitrogen of rations per day	Nitrogen in urine per day	Ammonia nitrogen in urine per day	Ammonia nitrogen in urinary nitrogen	Nitrogen of food in urine	Utilization of nitrogen	Nitrogen of food in feces
PERIOD I			*Grams*	*Grams*	*Grams*	*Percent*	*Percent*	*Percent*	*Percent*
2	Alfalfa hay		280.504	81.0495	0.5239	0.65	28.89	31.77	39.34
3	" "		226.040	49.6328	0.7192	1.45	21.96	37.28	40.76
4	" "		245.780	66.1871	0.4481	0.68	26.93	32.27	40.80
1	Clover hay		239.762	49.0082	0.7588	1.55	20.44	32.81	46.75
5	" "		239.762	45.4869	0.2657	0.58	18.97	31.08	49.95
6	" "		239.762	38.0211	0.6509	1.71	15.86	33.93	50.22
PERIOD II									
2	Alfalfa hay	Salt, 56 grams	338.466	103.8532	0.4931	0.48	30.68	27.83	41.49
3	Alfalfa hay	" "	260.378	61.4052	0.6679	1.09	23.58	34.44	41.98
4	Alfalfa hay; bone flour	" "	267.821	76.8859	0.3753	0.49	28.71	32.89	38.40
1	Clover hay; bone flour	Salt, 28 grams	253.683	54.3890	0.2306	0.42	21.44	32.71	45.92
5	Clover hay; calcium carbonate	" "	277.141	48.9173	0.2373	0.49	17.65	34.69	47.66
6	Clover hay; calcium carbonate	" "	253.683	43.3547	0.3491	0.81	17.09	38.21	44.70

TABLE XIII.—COEFFICIENTS OF DIGESTIBILITY OF RATIONS

Cow No.	Distinguishing features of rations		Protein	Nitrogen-free extract	Ether extract	Crude fiber	Nutritive ratio of rations
PERIOD I							
2	Alfalfa hay		79.463	78.18	64.495	48.83	1 : 6.27
3	" "		80.036	72.56	70.133	47.82	1 : 6.65
4	" "		80.850	76.00	70.243	52.97	1 : 6.47
1	Clover hay		74.608	73.71	73.368	49.34	1 : 8.06
5	" "		71.767	73.36	68.298	46.27	1 : 8.06
6	" "		72.290	71.58	72.199	48.41	1 : 8.06
PERIOD II							
2	Alfalfa hay	Salt, 56 grams	75.607	74.39	64.175	54.11	1 : 6.22
3	Alfalfa hay	" " "	75.805	72.00	70.479	49.19	1 : 6.66
4	Alfalfa hay; bone flour	" " "	77.579	78.32	68.951	49.53	1 : 6.43
1	Clover hay; bone flour	Salt, 28 grams	68.345	73.46	76.359	48.42	1 : 7.74
5	Clover hay; calcium carbonate	" " "	73.483	71.83	70.607	48.09	1 : 7.66
6	Clover hay; calcium carbonate	" " "	72.982	77.15	77.559	50.43	1 : 7.74

TABLE XIV.—PERIOD I, 1916: DISTRIBUTION OF OUTGO OF ELEMENTS AMONG MILK, URINE AND FECES (Percent)

Cow No.	Rations	Distinguishing features of rations	Sodium	Potassium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus	Nitrogen
			Milk Urine Feces	Milk Urine Feces	Milk Urine Feces	Milk Urine Feces	Milk Urine Feces	Milk Urine Feces	Milk Urine Feces	Milk Urine Feces
2	Corn; cottonseed meal; wheat bran; linseed meal; corn silage; alfalfa hay; salt	Alfalfa hay	58.84 38.76 2.40	24.27 62.29 13.44	25.38 0.95 73.67	7.75 14.44 77.81	20.51 39.87 39.62	48.20 31.25 20.55	46.23 0.31 53.46	33.84 28.02 38.14
3	Corn; cottonseed meal; wheat bran; linseed meal; corn silage; alfalfa hay; salt	"	52.89 30.49 16.62	31.81 53.58 14.61	36.22 0.61 63.18	11.39 13.89 74.72	27.92 28.81 43.27	53.24 26.43 20.33	49.09 0.29 50.62	37.75 21.79 40.46
4	Corn; cottonseed meal; wheat bran; linseed meal; corn silage; alfalfa hay; salt	" "	42.78 1.84 55.38	21.81 59.07 19.12	33.39 0.91 65.70	7.57 23.30 69.13	20.72 36.19 43.09	39.56 27.48 32.96	38.28 0.45 61.27	30.29 27.72 41.99
1	Corn; cottonseed meal; wheat bran; linseed meal; corn silage; clover hay; salt	Clover hay	72.75 6.92 20.33	20.22 42.52 37.26	34.05 3.84 62.11	5.73 22.47 71.80	27.46 16.38 56.16	54.91 13.27 31.82	35.49 0.29 64.22	35.08 19.75 45.17
5	Corn; cottonseed meal; wheat bran; linseed meal; corn silage, clover hay; salt	" "	42.81 3.21 53.98	22.27 52.70 25.03	28.94 0.13 27.93	4.92 0.65 84.43	22.32 16.56 61.12	67.77 0.88 31.35	37.44 0.30 62.26	29.21 19.49 51.30
6	Corn; cottonseed meal; wheat bran; linseed meal; corn silage, clover hay; salt	" "	66.66 7.40 25.94	23.89 49.53 26.58	37.34 0.62 62.04	6.42 12.42 81.16	29.46 13.23 57.31	66.71 0.88 32.41	39.44 0.26 60.30	35.45 15.49 49.06

TABLE XIV.—PERIOD II, 1916: DISTRIBUTION OF OUTGO OF ELEMENTS AMONG MILK, URINE AND FECES (Percent)

Cow No.	Rations	Distinguishing features of rations		Sodium Milk Urine Feces	Potassium Milk Urine Feces	Calcium Milk Urine Feces	Magnesium Milk Urine Feces	Sulphur Milk Urine Feces	Chlorine Milk Urine Feces	Phosphorus Milk Urine Feces	Nitrogen Milk Urine Feces
2	Corn; cottonseed meal; wheat bran; linseed meal; corn silage; alfalfa hay; salt	Alfalfa hay	Salt, 56 grams	26.59 48.24 25.17	20.28 66.01 13.71	19.47 0.35 80.18	6.90 12.08 81.02	17.41 40.64 41.95	37.10 42.24 20.66	41.53 0.28 58.19	29.54 29.96 40.50
3	Corn; cottonseed meal; wheat bran; linseed meal; corn silage; alfalfa hay; salt	Alfalfa hay	"	27.74 33.79 38.47	24.62 59.84 15.54	30.14 0.41 69.45	8.66 17.42 73.92	21.34 33.34 45.32	36.46 45.90 17.64	36.18 0.29 63.53	34.47 23.57 41.96
4	Corn; cottonseed meal; wheat bran; linseed meal; corn silage; alfalfa hay; salt; bone flour	Alfalfa hay; bone flour	"	19.59 32.89 47.52	19.69 66.10 14.21	24.37 0.53 75.10	6.49 23.03 70.48	19.40 38.83 41.77	27.13 40.73 32.14	31.52 0.30 68.18	32.43 28.90 38.67
1	Corn; cottonseed meal; wheat bran; linseed meal; corn silage; clover hay; salt; bone flour	Clover hay; bone flour	Salt, 28 grams	48.61 5.64 45.75	19.63 54.02 26.35	22.23 0.20 77.57	5.87 19.85 74.28	25.20 17.73 57.07	66.64 1.72 31.64	32.95 0.34 66.71	32.50 21.44 46.06
5	Corn; cottonseed meal; wheat bran; linseed meal; corn silage; clover hay; salt; calcium carbonate	Clover hay; calcium carbonate	"	39.62 29.71 30.67	21.42 60.17 18.41	23.95 0.08 75.97	5.01 12.82 82.17	23.25 16.64 60.11	66.68 1.05 32.27	43.20 0.27 56.53	31.48 18.52 50.00
6	Corn; cottonseed meal; wheat bran; linseed meal; corn silage; clover hay; salt; calcium carbonate	Clover hay; calcium carbonate	"	63.80 10.24 25.95	21.32 65.65 13.03	25.09 0.36 74.55	5.87 13.22 80.91	26.16 16.10 57.74	58.60 1.10 40.30	41.25 0.25 58.50	35.26 17.91 46.83

TABLE XV.—PERIOD I, 1915: DISTRIBUTION OF OUTGO OF ELEMENTS AMONG MILK, URINE AND FECES (Percent)

No.	Rations	Sodium	Potassium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus	Silicon	Nitrogen
		Milk Urine Feces	Milk Urine Feces	Milk Urine Feces	Milk Urine Feces	Milk Urine Feces	Milk Urine Feces	Milk Urine Feces	Milk Urine Feces	Milk Urine Feces
1	Corn; cottonseed meal; timothy hay; corn silage; salt	51.87 8.24 39.89	29.88 13.13 56.99	41.95 2.17 55.88	7.24 25.93 66.83	20.99 13.93 65.08	45.89 27.28 26.83	36.65 2.26 61.09	..... 1.17 98.83	34.02 17.33 48.65
2	Corn; cottonseed meal; timothy hay; corn silage; salt	59.22 25.01 15.77	31.08 17.64 51.28	35.66 2.62 61.72	5.25 20.29 74.46	21.44 21.18 57.38	57.55 15.09 27.36	37.65 5.34 57.01	..... 1.54 98.46	24.55 23.91 51.54
3	Corn; cottonseed meal; timothy hay; corn silage; salt	77.17 10.84 11.99	26.93 16.56 56.51	36.83 5.90 57.27	5.45 14.53 80.02	18.16 19.18 62.66	69.87 5.82 24.31	33.25 0.23 66.52	..... 1.06 98.94	24.18 21.67 54.15
4	Corn; cottonseed meal; clover hay; salt	51.01 42.96 6.03	25.24 59.45 15.31	23.55 ..... 76.45	6.27 21.63 72.10	29.99 14.61 55.40	83.61 ..... 16.39	43.72 4.23 52.05	..... 3.34 96.66	26.66 21.43 51.91
5	Corn; cottonseed meal; clover hay; salt	42.42 33.99 23.59	24.94 59.15 15.91	20.92 ..... 79.08	5.04 23.14 71.82	21.82 18.91 59.27	88.86 ..... 11.14	38.18 1.20 60.62	..... 1.63 98.37	18.89 32.86 48.25
6	Corn; cottonseed meal; clover hay; salt	44.48 39.31 16.21	26.61 50.22 23.17	21.91 ..... 78.09	6.11 24.34 69.55	22.31 16.94 60.75	81.10 ..... 18.90	42.22 0.50 57.28	.... 100.00	23.63 28.14 48.23

TABLE XVI.—PERIOD II, 1915: DISTRIBUTION OF OUTGO OF ELEMENTS AMONG MILK, URINE AND FECES (Percent)

Cow No.	Rations	Sodium	Potassium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus	Silicon	Nitrogen
		Milk Urine Feces	Milk Urine Feces	Milk Urine Feces	Milk Urine Feces	Milk Urine Feces	Milk Urine Feces	Milk Urine Feces	Milk Urine Feces	Milk Urine Feces
1	Corn; cottonseed meal; clover hay; corn silage; salt	68.35 30.39 1.26	24.74 60.14 15.12	25.87 0.14 73.99	5.69 21.26 73.05	25.24 15.72 59.04	55.09 1.43 43.48	45.11 0.39 54.50	..... 1.62 98.38	33.03 17.28 49.69
2	Corn; cottonseed meal; clover hay; corn silage; salt	43.81 31.79 24.40	23.95 60.99 15.06	22.23 0.20 77.57	4.70 22.23 73.07	23.06 18.40 58.54	62.84 0.84 36.32	47.12 0.72 52.16	..... 1.36 98.64	24.23 28.13 47.64
3	Corn; cottonseed meal; clover hay; corn silage; salt	64.03 33.28 2.69	23.66 63.08 13.26	24.57 0.11 75.32	4.44 19.16 76.40	23.64 18.29 58.07	72.44 0.65 26.91	50.04 0.32 49.64	..... 0.79 99.21	27.10 19.36 53.54
4	Corn; distiller's grains; clover hay; corn silage; salt	75.43 14.13 10.44	23.44 57.94 18.62	25.45 0.12 74.43	6.26 20.07 73.67	20.58 18.53 60.89	77.33 0.55 22.12	49.52 1.79 48.69	..... 1.02 98.98	27.27 24.67 48.06
5	Corn; distiller's grains; clover hay; corn silage; salt	59.87 16.72 23.41	24.90 59.96 15.14	22.81 0.13 77.06	6.33 21.51 72.16	19.85 19.22 60.93	79.60 0.69 19.71	44.57 0.57 54.86	..... 1.20 98.80	24.32 27.13 48.55
6	Corn; distiller's grains; clover hay; corn silage; salt	49.05 32.81 18.14	28.33 53.69 17.98	25.31 0.27 74.42	7.25 22.29 70.46	23.15 18.98 57.87	65.26 6.21 28.53	54.88 0.28 44.84	..... 0.60 99.40	30.11 22.21 47.68

TABLE XVII.—PERIOD III, 1915: DISTRIBUTION OF OUTGO OF ELEMENTS AMONG MILK, URINE AND FECES (Percent)

Cow No.	Rations	Sodium	Potassium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus	Silicon	Nitrogen
1	Corn; linseed oilmeal; clover hay; corn silage; salt	68.78 11.90 19.32	23.89 58.89 17.22	24.88 0.02 75.10	6.08 21.86 72.06	28.10 16.61 55.29	61.96 2.40 35.64	45.74 0.31 53.95	..... 1.62 98.38	33.73 21.22 45.05
2	Corn; linseed oilmeal; clover hay; corn silage; salt	51.65 13.37 34.98	20.19 64.16 15.65	24.43 0.03 75.54	4.06 19.79 76.15	22.76 19.45 57.79	62.08 0.77 37.15	39.26 0.59 60.15	..... 1.30 98.70	25.91 28.58 45.51
3	Corn; linseed oilmeal; clover hay; corn silage; salt	45.85 14.74 39.41	21.28 66.39 12.33	23.49 0.02 76.49	4.27 20.43 75.30	22.94 19.06 58.00	76.07 0.70 23.23	40.87 0.38 58.75	..... 1.83 98.17	24.28 25.77 49.95
4	Corn; gluten feed; clover hay; corn silage; salt	61.54 21.38 17.08	18.82 59.96 21.22	25.83 0.03 74.14	4.66 20.73 74.61	18.03 29.29 52.68	70.75 0.72 28.53	37.01 11.07 51.92	..... 2.08 97.92	27.22 26.26 46.52
5	Corn; gluten feed; clover hay; corn silage; salt	69.51 3.25 27.24	19.37 57.81 22.82	19.84 0.21 79.95	4.40 20.45 75.15	18.51 28.79 52.70	69.76 0.36 29.88	30.15 0.47 69.38	..... 1.76 98.24	24.79 27.15 48.06
6	Corn; gluten feed; clover hay; corn silage; salt	53.32 26.74 19.94	18.86 51.42 29.72	23.60 0.09 76.31	4.55 21.66 73.79	19.09 29.27 51.64	51.72 3.38 44.90	37.62 0.29 62.09	..... 1.22 98.78	27.92 25.35 46.73

THE MINERAL METABOLISM OF THE MILCH COW

THIRD PAPER

OHIO Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., SEPTEMBER, 1918

BULLETIN *330*

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THE MINERAL METABOLISM OF THE MILCH COW

THIRD PAPER

PART I—THIRD EXPERIMENT

E. B. FORBES, J. O. HALVERSON AND L. E. MORGAN WITH
COLLABORATION BY J. A. SCHULZ, C. E. MANGELS, S. N. RHUE
AND G. W. BURKE

The cow is foster-mother of the human race. This relation, older than the art of writing, grows in prominence as a factor in nutrition with our advance in the science of living; and on both physiologic and economic grounds we anticipate continued increase in the contribution of the cow to the human diet.

This expectation is based on the facts that among farm quadrupeds the cow is by far the most economical producer of protein nutriment; that among proteins in general those contained in milk possess a maximum nutritive value; that milk possesses other important growth-promoting principles the exact nature of which is as yet unknown, and that no other food carries such an abundance of mineral nutrients of desirable kinds and combinations. No other food has an equal value for the general purpose of health insurance.

Since milk is preeminently a protein food it is natural that the protein requirement of cows should have been worked out with great elaboration, and that successful production should depend on a practical recognition of the cow's imperative need for the protein raw material which she transforms.

The fact that the cow is also unparalleled as a producer of mineral nutriment, and that her mineral food requirements must be of a corresponding order, appears to have been overshadowed by the more prominent facts as to her nitrogen metabolism; and we have not been obliged to study the cow's mineral metabolism since, in the provision of her more obvious requirements, we have incidentally and unintentionally done fairly well in providing the necessary

mineral substances. In this day of rigorous searching for the tru inwardness of things, however, we should no longer delay a caref examination into the terms on which the cow conducts her extensi mineral exchange.

During the past 3 years the main line of work of this depar ment has been an investigation of this subject. This program h embraced three experiments, with six cows in each. There we three experimental periods in the first test and two in each of t others. Our conclusions rest, therefore, on 42 individual studi

The results from the first and second of these experiments ha been published as Bulletins 295 and 308 of the Ohio Experime Station. The results of the third experiment are presented in th paper, together with a discussion covering the results of the enti series.

OBJECTS OF THE EXPERIMENT

The general object of this investigation was to study t mineral metabolism of the milch cow under conditions such that t results would bear directly on the practical management of da cattle, to elucidate the terms on which the extensive mineral change of the cow is conducted, and to determine the conditi under which mineral equilibrium may be maintained during pro able milk production.

The first of these experiments was a study of common, pra cal winter rations composed of hay, corn silage, corn meal a protein concentrates. The several rations differed as to kind of h (clover or timothy), or kind of protein concentrate (cottons meal, linseed oilmeal, distiller's grains or gluten feed).

The rations in the second experiment were similar to those the first, but the hay was in each ration either clover or alfal and these mineral-rich rations were further fortified, in cert cases, by the addition of steamed bone flour or of calcium carbon

In the third experiment, the detailed results of which are h presented, the mineral nutrients of the basal rations were increa by the dropping out of corn silage, and the use of alfalfa hay as sole roughage; then, in certain cases, these rations were sup mented by the addition of precipitated bone flour, calcium lac or calcium chloride; these particular calcium preparations b chosen on account of their ready solubility, the chloride and lac being water-soluble, and the precipitated bone flour (largely in dicalcic form) being readily soluble in acid.

The rations of the three experiments, therefore, constitute a progressive series in the amounts and solubility of the mineral nutrients. The mineral contents of the rations of the third experiment may be considered as approximating the maximum practicably attainable.

Briefly stated, the object of the first experiment was to study types of rations used in practice; of the second to determine the effects of steamed-bone flour and calcium carbonate when administered in the ration; and of the third to study the more readily soluble precipitated bone flour, calcium lactate and calcium chloride, also when used as supplementary foods.

METHOD OF EXPERIMENTATION

The method of this study, as also that of the preceding two, involved the complete chemical accounting for food, milk, urine and feces. Details of procedure were the same as published in Bulletin 295. As in the earlier experiments, six Holstein cows were used, in collection periods of 20 days each (except where shorter periods were necessitated by irregular behavior of the subjects). These periods were separated by 10-day intervals on the ration to be used in the collection period to follow. The cows, during the experiment, had not been bred. They were fed and milked four times daily, at 6-hour intervals. As to quality they were good, profitable cows, better than the average, but of a grade readily attainable by selective breeding. They were cows such as a successful commercial dairyman expects to have.

During the preliminary feeding the amounts of the feeds were so adjusted that they would be consumed without waste, and there were no refused feeds to be accounted for. The amounts of the mineral supplements to be administered were determined by trial during the preliminary feeding. Varying individual tolerance for these salts was manifest. It was necessary in four cases out of the twelve to start the collection period late, or to terminate it early, on account of unsatisfactory behavior of some one of the experimental subjects.

RATIONS

The basal ration fed was composed of the same feeds in all cases. These were corn meal, cottonseed meal, linseed oilmeal, wheat bran and alfalfa hay. The nutritive ratios of the digested nutrients during the first period averaged 1:5.72. During the second period the additional amounts of alfalfa hay given served to increase the proportion of protein to non-protein to 1:4.50.

In Period I, Cows 1, 2 and 3 received the basal ration alone, while Cows 4, 5 and 6 received the same ration plus precipitated bone flour.

In Period II, Cows 1, 2 and 3 received the basal ration plus calcium lactate, while Cows 4, 5 and 6 received the same plus calcium chloride.

These rations may be considered, then, as closely approximating maximum nutritive value, and possessing all of the characteristics of high-class milk-producing rations except that they contained no succulent feeds such as silage or roots.

RESULTS OF THE EXPERIMENT

Table I, page 119, sets forth the total amounts of feeds consumed and of milk produced, and the live weights of the cows. In consideration of the natural variability of the live-weight of a cow there were no notable changes in the weight of the experimental subjects, except in the case of Cow 6 in Period II. Here the apparent gain in weight doubtless represented actual increase in body substance. In general, as in the previous experiments, the live weights were maintained practically constant, and, in the consideration of the experimental data, we may dismiss from our mind the factor of gain or loss in body weight.

The statement of the number of days each cow was fed, in the first column of the table, indicates that in four cases it was necessary to depart from the plan of the experiment, on account of accident or irregularity of behavior of the cows. In the case of these individuals which were not fed for the full 20 days the element of inaccuracy in the results was undoubtedly higher than in other cases, and due weight should be given this fact in the interpretation of the data.

Table II, page 120, records the daily amounts of feeds consumed and of milk produced, in grams. A statement of the same matter in pounds, may be found in Table XI, page 130. It will be observed that the nitrogenous concentrates were fed at all times in the proportion of 2 parts cottonseed meal, 2 parts linseed oilmeal and 1 part wheat bran.

In Period I we fed 16 pounds each of grain and hay. Of the grain 11 pounds was corn meal, and 5 pounds was nitrogenous concentrate. The daily milk production in the case of the cows which were on feed for the full 20 days was 47.2 pounds. These figures will indicate to the dairyman that the cows were full-fed. In

maximum production and profit the rations could have been improved by the introduction of corn silage, and reduction of the amount of grain.

In Period II the basal ration was the same as in Period I, except that on account of the hunger of the cows, due largely to lack of bulk in the ration, the alfalfa hay was increased to 18 pounds per day. The milk production of the cows which were on feed the full 20 days averaged 49.9 pounds each, per day.

The amount of precipitated bone flour fed to Cows 4, 5 and 6 in Period I was arbitrarily fixed. The calcium given in this form amounted to 17.1173 gm. per head per day. No difficulty was experienced in the feeding of this preparation. Animals will eat it in indefinite quantities. The calcium lactate fed to Cows 1, 2 and 3 in Period II was not so well taken. The amounts administered to Cows 2 and 3 required careful adjustment and readjustment. Cow 1 consumed the full amount offered her for the full 20 days. The calcium fed these three cows in this form was 15.3602 gm., 7.9259 gm. and 12.4892 gm., respectively, per day.

Table III, page 121, indicates the composition of the feeds. These were not far from normal, except for the cottonseed meal, which contained 19.04 percent of crude fiber and only 23.51 percent of protein. Obviously this product was grossly adulterated with ground hulls. In case of the calcium lactate several lots were used, and not all of them were subjected to complete analysis, the content of certain constituents which were present in small amounts being assumed (as indicated by parentheses) from the analysis of other lots received from the same manufacturer.

Among the notable details of composition of these feeds are the high potassium content of the alfalfa fed in Period II, the characteristically high calcium content of both samples of alfalfa, the low calcium content of the corn meal, the high phosphorus content of the wheat bran, and the high silicon content of the linseed oilmeal and alfalfa hay.

Table IV, page 122, records the composition of the milk. It is a well-known fact of physiology that the composition of cow's milk cannot be altered in important ways, through the character of the feed, so long as the cow remains in a normal state of health, though the evidence on this subject does not preclude the possibility of any such effect whatever. Such being the situation we draw no conclusions from this work, as demonstrating specific effects of the mineral supplements used, on the composition of cow's milk, but would call attention to the fact that, in comparing the milk of Cows

4, 5 and 6 in Period I with the same in Period II, the three differ together (that is, in the same direction), as to ash, sodium, calcium, potassium, sulphur and phosphorus contents. In all cases these differences are slight, and perhaps within the normal range of variation.

Table V, page 123, records the amounts of the constituents of the average daily rations. The main differences in the totals of the nutriment of a given kind, as fed in the two periods, are due to the increase in the alfalfa hay fed in Period II above the amount fed in the previous period, and also to marked differences in the composition of the hay fed in these two periods. The alfalfa fed in Period I was grown in Ohio, and that fed in Period II was grown in the far west, being purchased in the Chicago market.

The influence of these differences in the amount and source of the hay are reflected in the increased amounts of nitrogen, nitrogen free extract, calcium, potassium, sulphur, chlorine and silicon, and decreased amounts of sodium and magnesium present in the ration fed in the second period.

Tables VI, VII and VIII, pages 124 to 126, set forth the amounts of the constituents present in the milk, urine and feces, and are included merely for the sake of convenient reference, and for the completion of the records.

The main results of the experiment, the balance data for the mineral elements and nitrogen, are reported in Tables IX and X, pages 127 and 128. Considering the results for Period I, these data afford a basis for judging of the effects of adding precipitated bone flour (Cows 4, 5 and 6) to the basal ration (Cows 1, 2 and 3). Since the facts must be judged by the comparison of results from different cows we can draw conclusions only from extensive and therefore unmistakable differences.

The only significant effects observed, of the feeding of the bone flour, were probable decreases in the losses of calcium and phosphorus from the body. Omitting Cow 2 from this consideration the calcium loss in Cows 1 and 3 averaged 10.320 gm., and in Cows 4, 5 and 6, which received the precipitated bone flour, the loss was 5.999 gm.; and the latter group, with their heavier milk production also had the greater calcium need. The difference between the calcium intake of the two groups was 17.117 gm. Phosphorus retention was indicated by the fact that whereas the loss of phosphorus from the bodies of Cows 1 and 3 averaged 5.983 gm. the loss from Cows 4, 5 and 6 which received the bone flour, was but 1.8 gm. per head per day.

The balances of income and outgo during this period were almost all negative; that is, there was a loss of minerals. Only in the case of sodium does the intake appear to have fulfilled the requirements. In almost all cases, however, the intake of the several elements greatly exceeded the combined amounts of the same found in the milk and urine; and in the cases of potassium, magnesium and sulphur, in spite of negative balances, there was in each case a greater quantity of these elements in the urine than in the milk; also, large amounts of these elements appeared in the feces. This general situation appears not to have been influenced in any certain way by the relative solubilities of the compounds of the elements in question. The results, therefore, indicate conditions unfavorable for mineral retention rather than deficient intake of the same.

Turning now to Table X, page 128, these data apply to the same six cows referred to in the previous table, and furnish a basis for comparison of the results of adding calcium lactate and calcium chloride to the basal ration. This comparison would be made from results obtained with different cows; but by the comparison of results in Table IX with those in Table X we are also able to study two treatments applied to the same cows in two groups of three individuals each.

First, comparing the balances for Cows 1, 2 and 3 in Periods I and II, the differences in feeding are that in Period II the amount of alfalfa hay was increased, and a different lot of hay, differing much in composition, was used; and calcium lactate was added to the ration. One should also bear in mind the fact that since Cow 2 in Period I and Cows 2 and 3 in Period II were in the test for 8 to 10 days only emphasis on the results should be placed accordingly.

The significant differences in the intake caused by the above-mentioned changes of ration were a slight decrease in sodium and magnesium, slight increase in phosphorus, and marked increase in potassium, calcium, sulphur, chlorine and nitrogen.

The decrease in sodium intake seems to have lowered the sodium retention, the reduced intake of magnesium seems also to have produced slightly decreased retention, but the differences are of doubtful significance. The slight increase in phosphorus intake caused a slightly greater retention of this element. The large increases in potassium and nitrogen caused decided improvement in their retention; the large increases in sulphur and chlorine caused but slightly improved retention, while there is no evidence that any part of the extensive increase in calcium was retained, in fact, the negative calcium balances were in every case increased.

Let us now compare the balances for Cows 4, 5 and 6 in the two periods. In this case there is the previously mentioned difference in amount and composition of alfalfa; and further, the mineral supplement was precipitated bone flour in Period I and calcium chloride in Period II. These differences in treatment resulted in slight decreases in the intake of sodium, magnesium and phosphorus, and large increases in the intake of potassium, calcium, sulphur, chlorine and nitrogen in Period II as compared with Period I.

The slight decreases in sodium and magnesium intake usually caused slight decreases in the retention of these elements, but a similar decrease in the intake of phosphorus caused no certain change in phosphorus retention.

The large increases in the intake of potassium, sulphur, chlorine and nitrogen all caused definite improvement in the retention of these elements, but, as before, the greater calcium content of the ration in Period II was accompanied by increased loss of this element.

Now, comparing the balances for Cows 1, 2 and 3 with the same for Cows 4, 5 and 6, in Period II, we observe the effects of the difference between calcium lactate and calcium chloride. As before observed we had difficulty in the feeding of the lactate to Cows 1 and 3; on this account our only entirely satisfactory basis for judgment as to the metabolism of this compound is furnished by Cow 1. This comparison gives us but two points worthy of record; the very great increase of chlorine in the ration, due to the feeding of calcium chloride, caused a slight but definite increase in the chlorine retention, and a larger increase in the retention of sodium. The calcium of these two supplements seems not to have been retained.

The most important fact developed by these data is that, irrespective of conditions, and in spite of large intake of calcium, the element was eliminated in quantities greater than were contained in the feed. There is but slight evidence that the precipitated bone flour was utilized, and no evidence that the calcium lactate or the calcium chloride were utilized; there is no evidence, therefore, that the limited utilization of calcium by milk-producing cows is due to the limited solubility of the calcium compounds of the ration.

It is worthy of note, also, that the cows were markedly irresponsive to the intake of magnesium and phosphorus, with which calcium is combined in the skeleton, and that the balances for these elements remained almost invariably negative in spite of the presence in the rations of amounts of the same very much greater than were utilized.

The fact that the heavily-milking cow loses calcium at the same time that she receives a readily assimilable supply greatly in excess of the amount utilized shows that the calcium stores of the body (the skeletal stores) are more readily accessible for use in milk production than is the calcium of the ration.

The cow can store fat and protein in considerable quantities in spite of heavy milk production, but her capacity to assimilate mineral matter, especially calcium, appears to be of a distinctly lower and more definitely limited order.

Common salt was fed in the amount of 42 grams per day to each cow. This furnished from two-thirds to four-fifths of the total sodium of the rations, and permitted considerable storage of this element. The accompanying chlorine, however, was insufficient to meet the demands of milk production, since the chlorine balances were all negative, except where an extra amount was given in the form of calcium chloride to Cows 4, 5 and 6 in Period II. With these three cows there was chlorine retention, the amounts stored (1.261-2.378 grams) being comparatively small. The chlorine intake which resulted in loss from the body was 31.450 to 53.751 grams; where retention of chlorine occurred the intake was 79.412 grams. The requisite amount is undoubtedly affected in a prominent way by the extent of the milk production.

The potassium intake in Period I (88.671 to 105.788 grams) seemed to be insufficient to maintain potassium equilibrium. In Period II the change in amount and kind of alfalfa increased the intake of potassium to 245.069-294.503 grams, and the balance became positive, the storage being 6.415 to 10.738 grams per day.

From these data it would appear that a ration containing as much as 16 pounds of alfalfa hay might be deficient in potassium, but it may be that both the positive and negative balances of potassium represent unimportant fluctuations in extensive reserves of this element.

Eleven out of the twelve sulphur balances were negative. In considering the significance of sulphur balance data one naturally compares them with the associated nitrogen balances, since these two elements are consumed almost wholly in chemical combination in the protein of the ration.

Both sulphur and nitrogen balances were negative in Period I. In Period II there was marked increase in the intake of both of these elements. Nitrogen balances became positive, and the losses of sulphur were reduced, the balances, however, remaining negative. In these rations, therefore, an amount of protein sufficient to pro-

vide for nitrogen storage failed to provide enough sulphur to maintain equilibrium of this element.

Table XI, page 129, is presented merely as a convenient summary of the data contained in the two preceding tables, but with the amounts of feeds consumed and of milk produced expressed in pounds. The average daily intake and balances of the nutrient elements are stated in grams.

Table XII, page 131, presents a computation of the amounts of the mineral elements of the rations expressed in terms of cubic centimeters of normal solutions; also a statement of the total acid and total base, and of the amount of the excess base in the rations. The result of this computation is not considered as applying closely to the physiology of mineral metabolism, but merely affording a basis for a general idea as to the relative amounts of acid and base in the feeds.

Calcium and potassium are shown to be the predominant bases while phosphorus is the predominating acid element in these rations Silicon is also shown to be present in considerable quantity, and on this basis of computation, to exceed chlorine. No distinction was made, however, between the silicon present as insoluble silica and that contained in the feeds in the form of readily soluble silicates The fact that silicon enters into the mineral metabolism of the cow and so must be considered in connection with this acid-base balance was observed in the first of this series of investigations (Bul. 295)

Table XIII, page 132, exhibits data on the utilization and elimination of nitrogen. On a number of accounts conditions were not favorable for close comparisons of results with reference to nitrogen metabolism; thus, the nitrogen intake in Period II was much greater than in Period I; the proportion of the total nitrogen of the rations in Period II which was contributed by alfalfa hay was also greater than in Period I; further, this hay was of a different lot and differed much in composition from the hay fed in Period I. considerable amount of individuality is manifest in the behavior of the cows, especially those which on account of unsatisfactory behavior were not in the experiment for the full periods. As much as we are able to say in regard to these data is that they do not show any effects of the mineral supplements on the nitrogen metabolism. Since nitrogen and mineral metabolism are to a large extent independent there is no reason to suppose that a particularly different conclusion could have been drawn even if the conditions for the observation had been more favorable.

Table XIV, page 132, records the digestion coefficients of the protein, nitrogen-free extract, ether extract and crude fiber of the rations. No correction was made for metabolic nitrogen, since investigations in this laboratory have shown that we have, in reality, no scientific basis for a method of making such an estimation. The nutritive ratios of these rations were computed from the data for intake and feces for each cow. A considerable degree of variability is observable in these digestion coefficients, but there is neither certainty nor even probability that the digestion coefficients were modified by the mineral supplements fed. The nutritive ratio in Period II was narrower than in Period I, because of the differences, which have been mentioned, in the amount and composition of the alfalfa hay.

Tables XV and XVI, pages 133 and 134, display the percentages of the total outgo of the several elements between milk, urine and feces. It will be observed that the percentages of the total outgo of sodium, potassium and chlorine found in the milk were less in the case of each cow in the second period than in the first.

In the case of sodium the amount as well as the percentage in the milk was lower in the second period, as was also the sodium intake, but such was not the case in regard to potassium and chlorine.

The main chemical fact upon which is based the behavior of these elements in the eliminative process is the ready solubility of their compounds, and one of the chief physiological considerations which contribute to the determination of the path of outgo is the length of time the food or food residues remain in the alimentary tract. In accord with individual conditions in the digestive tract, then, there may be great variability in the relative outgo of these elements in urine and feces, but, except in cases of digestive disorder, the proportion of the outgo occurring in the urine usually greatly exceeds that occurring in the feces.

The significance of the lower percentages of the outgo of these elements in the milk in Period II than in Period I is most readily comprehended by directing the attention to the intake of these elements and to the outgo in urine and feces.

In the case of sodium 29.5 percent of the total in the rations in Period I were contributed by alfalfa; in Period II only 14.7 percent of the sodium was contributed by this feed, the amounts contributed by other feeds remaining the same. The data signify in relation to sodium, then, that with a larger sodium intake, a larger proportion of which was contributed by alfalfa, a larger amount

and proportion of the sodium outgo appeared in the milk; and of the remainder a larger proportion occurred in the feces (in five cases out of six). In this connection it seems judicious to remark that the difficulties in the way of accurate sodium estimations are great; and that the path of outgo of sodium is often determined by conditions as to the nature of which we can but speculate.

In the case of potassium and chlorine the smaller proportion of the total outgo occurring in the milk in Period II is not due to smaller amounts in the milk, but to much larger intake, the amounts in the milk remaining about the same. The great increase in the intake of these elements was nearly all absorbed, and excreted in the urine.

No effect of the larger ingestion of chlorine as calcium chloride by Cows 4, 5 and 6 in Period II was observable in the quantitative excretion of the bases. This chlorine was eliminated in the urine probably in combination with bases ingested as organic acid salts, thus serving to reduce the carbonate content of the urine.

This investigation revealed no unmistakable effects of the mineral supplements administered on the paths of outgo of calcium, magnesium and phosphorus.

Sulphur left the body in the case of each cow in larger proportion in the urine than in the milk. At the same time 11 out of the 12 sulphur balances were negative. In Period I more sulphur was eliminated in the feces than in the urine, but in Period II, with an increased sulphur intake, there was in each case an increase in amount and proportion of sulphur in the urine. There was some increase in the retention of sulphur in each case, but five out of the six sulphur balances remained negative. There is no evidence of an effect of the mineral supplements on the path of outgo of the sulphur.

Nitrogen is not closely related to the minerals in their metabolism, and we observed no evidence in the data on outgo of nitrogen to indicate such a connection. The elimination and retention of nitrogen was not shown to be affected by circumstances other than the intake of this element. The intake in Period I was slightly deficient; the liberal increase in Period II is reflected in improved retention, with change of balances from negative to positive, increased proportion of outgoing nitrogen in the urine, and decreased proportion in milk and feces.

SUMMARY OF RESULTS

This experiment consists of a study of the metabolism of certain readily soluble inorganic salts and preparations, namely calciu

chloride, calcium lactate and precipitated bone flour during the height of the milk flow.

The feeding of precipitated bone flour to cows, during heavy milk production, and in a period characterized by outgo of calcium and phosphorus in amounts greater than the intake, appears to have resulted in the retention of appreciable amounts of the calcium and phosphorus of this supplement, but the utilization was strikingly inefficient, in fact the mineral metabolism as a whole was characterized by a failure to make economical utilization of these elements of the ration.

The calcium of calcium lactate and calcium chloride was not retained, but the chlorine of calcium chloride appears to have been retained in slight proportion, and to have rendered possible an increased retention of sodium from the ration.

In general, the differences in the utilization of the mineral nutrients, caused by changes in the ration, were in harmony with the nature of the change; that is, an increase in the intake of an element was usually followed by an increased storage, or decreased loss, of this nutrient, but the response was usually so slight, in comparison with the extent of the change of intake, that it became apparent that the mineral metabolism of the well-fed, heavily milking cow is not intimately and directly dependent upon the mineral nutrients of the ration, but that its character is determined under normal conditions first by the inherited impulse to secrete milk, second by the mineral nutrient reserves of the animal body, and only third by the food supply.

The most important result of this experiment was the demonstration of the fact that the limited utilization of the mineral nutrients, especially of compounds of calcium, is not determined primarily by their conditions as to solubility.

Common salt in the amount of forty-two grams per head per day provided for the storage of sodium, but furnished an insufficient supply of chlorine. Chlorine was stored only where an added amount was fed in the form of calcium chloride.

The potassium balances indicate that a ration must contain an abundance of roughage in order to maintain equilibrium of this element. With hay only as a roughage; that is, without silage, it is not always possible to maintain the body stores of potassium, but it is true that under some circumstances it is impossible to determine whether negative potassium balances signify actual deficiency of this element in the ration or only unimportant fluctuations in a body supply normally maintained at a level providing liberal factor of safety.

In this experiment an intake of protein sufficient to provide for nitrogen storage was insufficient to maintain the sulphur equilibrium. In spite of a general harmony in the metabolism of sulphur and nitrogen, as would be anticipated on account of their combination in the proteins of the foodstuffs, there is a degree of independence in the metabolism of these two elements the signif-cance of which is not explained by our data.

In spite of superabundant supplies of calcium, magnesium and phosphorus in the rations the balances of calcium and phosphorus were in every case negative, and of magnesium eleven balances out of twelve were negative.

Some of the main facts determining the path of outgo of sodium, potassium and chlorine are their ready solubility and the length of time the food residues remain in the alimentary tract. The chlorine of calcium chloride was eliminated in the urine, and the calcium in the feces.

Calcium and phosphorus were eliminated almost wholly in the feces; that is, the urine contained but very little of either; the milk, however, contained an abundance of each (always more cal-cium than phosphorus), and a larger proportion of the food phos-phorus than of the food calcium.

Magnesium was excreted in the urine in much greater quanti-ties than either calcium or phosphorus. In eight cases out of twelve more magnesium was eliminated in the urine than in the milk, but in eleven cases out of twelve the total magnesium outgo exceeded the intake.

Sulphur, likewise, left the body in each case in larger propor-tion in the urine than in the milk, but in eleven cases out of twelv the sulphur outgo exceeded the intake. The path of outgo of sul-phur, as between urine and feces, is much affected by the amoun of sulphur intake.

The nitrogen retention is controlled closely by the intake, an is not at all closely related to the mineral metabolism. Increase nitrogen intake, until a limit is reached, causes commensurate in crease in retention, and increase in the proportion of the total outg appearing in the urine.

PART II—SUMMARY OF RESULTS FROM THE THREE YEARS' WORK, WITH A DISCUSSION OF PRACTICAL BEARINGS

These results were obtained with high-grade Holstein cows good productive capacity, most of them from 4 to 6 years of a during the first half of the period of lactation, and in the winter a

arly spring months. They were confined in stalls in a cool room, ad were given no unrestricted exercise, but the stalls allowed considerable freedom of movement. They were not bred during these vestigations. In most essentials the conditions of feeding and are closely approximated those existing in practice. There were, general, no significant changes in live-weight.

This series of experiments affords us opportunity for a considerable number of comparisons of feeds and of mineral supplements in their effects upon mineral metabolism; thus clover hay is mpared with timothy hay and with alfalfa hay; among protein ncentrates cottonseed meal, linseed oilmeal, gluten feed and distiller's grains are compared; and among mineral supplements we ave compared steamed bone flour, precipitated bone flour, calcium rbonate, calcium lactate and calcium chloride.

Sodium and Chlorine.—The common salt fed in the several riods was in the amount of 28, 42 or 56 grams per head per day. thirty-one balances out of forty-two sodium was stored, and likeise chlorine in twenty balances. There is some indication in e data that the requirement for chlorine is decidedly greater than or sodium, but the facts are obscured by the difficulties met with n the estimation of sodium, and by the fact that the outgo of these lements from the body may be prominently affected by such conitions as temperature, water drunk, and rapidity of passage of the od through the alimentary tract.

The cow normally carries a considerable excess of both of these lements in the body, which can be drawn upon in considerable mounts without injury to the animal, in the event of temporary hortage. The natural tendency of the cow is to maintain equibrium of these elements at a high level of reserve supply. Conderable gain or loss of these elements during 20-day balance riods may represent only fluctuations in the reserve, without gnificant bearing on actual requirements. Neither can be stored indefinitely. There is a large measure of independence in the etabolism of chlorine and the bases with which it is united in the od; thus, the chlorine of calcium chloride may all be eliminated the urine, while at the same time its calcium is all eliminated the intestine; and considerable independence in the elimination sodium and chlorine is also manifest at times. The normal serves of these elements are so extensive that the accurate deterination of the real nutritive requirements would call for an tended investigation, in point of time.

For practical purposes it is sufficient to feed a cow from 1 to ounces of common salt per day, according to whether she is a mo erate or heavy milker, and then, as a safety provision, to allo free access to rock salt in addition.

Comparing the chlorine of the intake, urine and feces of o period with another, when the intake was low the urinary chlori was lower than the feces chlorine. The chlorine of the urine e ceeded that of the feces only when the intake was high. With ve low intake the chlorine disappeared from the urine, but considera amounts remained in the feces; or, stating the matter in anoth way, when the intake was very low the apparent absorption mained incomplete, and all or nearly all of that which was absorb went into the milk.

The conditions governing the elimination of sodium are co plex, and are not readily analyzed. Urinary sodium exceeded fecal sodium in twenty-two out of forty-two cases. The distri tion was not determined directly by the intake; it appeared to an individual peculiarity of the animal, the length of time the f residues remained in the digestive tract being one factor of imp tance. In some cases nearly all of the sodium was excreted in urine, while in others it was almost all in the feces.

Potassium.—The potassium intake was probably more t sufficient in all cases, since the amount of this element elimina in the urine always greatly exceeded the amount in the milk; at same time there were nine negative balances out of the forty-t the significance of which is not explained with certainty. Ap ently these negative balances signify only unimportant fluctuat in extensive reserves.

Potassium was eliminated in the urine in amounts very n greater than in the feces in all cases except where timothy was fed. (See Bul. 295, page 342.) This timothy hay, lar through its high silicon content, rendered the urine acid, u which circumstances the potassium was eliminated in the much more largely than in the urine.

Nitrogen and Sulphur.—Nitrogen was retained in twenty- out of the forty-two cases. Of the thirteen negative balances s occurred during the feeding of the basal or unsupplemented rat Nitrogen storage prevailed in 86 percent of the cases where mi supplements were used. There is no evidence, therefore, that vailing negative balances were in any way due to the state o nitrogen metabolism; in fact, throughout this investigation is no evidence of any direct relation between the nitrogen an

ineral metabolism, except that there is a general parallelism in the etabolism of nitrogen and sulphur, by virtue of their combination n the proteins, but even here the agreement is by no means com-lete, since in nine cases out of forty-two the signs of the balances iffered; that is, one of these elements was stored while the other as given off in amounts greater than the intake. These differ-nces may depend upon the considerable variation which exists in he relative amounts of nitrogen and sulphur in the nitrogenous tructures of the body, referring especially to keratin and muscular issue.

That there is a relation between the metabolism of nitrogen nd each of the mineral nutrients is undoubtedly a fact, but the onnection is not readily demonstrable, and ordinarily becomes anifest only as the general health of the animal is affected through ng-continued nutritive deficiency.

The nitrogen of alfalfa hay was more digestible than the nitro-en of clover hay, but the percentage of utilization in both cases as the same. This observation is equally true, whether we con-ider the total feces nitrogen as indigestible or whether we estimate, nd consider as digestible, that fraction of the feces nitrogen which of metabolic origin. It is possible, however, that this interesting ifference which we have observed in the digestibility of the nitro-en compounds of clover and alfalfa hay without such difference n the utilization of the same, was characteristic only of the par-icular samples of hay involved, and not of these two roughages n general.

The proportionate elimination of sulphur in urine and feces as controlled by the amounts and kinds of feeds consumed, and not parently by the amounts of the other mineral elements.

In rations the roughage of which was clover hay the urinary lphur was commonly one-third or one-fourth as great in amount the feces sulphur, but gluten feed, which is rich in sulphur, ssesses a marked tendency to increase the proportion of urinary lphur, as does also alfalfa hay. With heavy consumption of falfa hay the urinary sulphur was always high, and sometimes ceeded the quantity in the feces.

Approximately three-fourths of the urinary sulphur was in the rm of sulphates. Ethereal sulphates in all cases exceeded inor-nic sulphates in amount, but the relative amounts of these two oups of compounds were subject to such very wide variation, in cord with the state of metabolism of the individual animal, that specific statement is possible, regarding this matter, which plies in the several experimental periods.

Silicon.—An extensive metabolism of silicon was demonstrate in the first experiment of this series. From 15.617 to 24.925 gram per day of this element was retained during the feeding of timoth hay. The retention was much less when the roughage used wa alfalfa or clover. This was in harmony with the silicon content the rations. The urine was acid during this period of high silic intake, but not under any other circumstances during these expe ments. Silicon was found in considerable quantities in the urin but not in weighable amounts in milk. Its presence in milk, ho ever, has been demonstrated. Approximately half of the miner acidity of the ration containing timothy hay was due to silicon.

Calcium, Magnesium and Phosphorus.—These elements a associated in metabolism because of the limited solubility of th compounds, and because they occur in the animal body, in mi and in the excreta largely in chemical combination. The most u expected results of this investigation have to do with this gro of elements.

The rations used, considered as a group, were characteriz by high contents of calcium, magnesium and phosphorus. T amounts of each present in the feed greatly exceeded those in t milk produced, except in one instance, that of the ration containi timothy hay, in the first experiment. Here the calcium intake v obviously low.

In all cases the intake of magnesium exceeded the appar requirement by a much larger proportion than did the intake calcium and phosphorus.

The most prominent fact regarding the metabolism of th three elements is the lack of direct bearing of the intake upon balance; that is, there was a conspicuous failure of the cows utilize these constituents of the rations, when negative balan indicated that the apparent physiological need for them was fully satisfied. Thus, in spite of the fact that the intake of th elements was usually greatly in excess of the apparent requirem the outgo of calcium exceeded the intake in every one of the fo two balances. The basal rations were naturally rich in these ments, and the supplemented ones contained large additi amounts of these nutrients in the shape of readily available i ganic compounds.

While there was calcium loss in every case, there was n nesium loss in 95 percent and phosphorus loss in only 79 per of the balances. A considerable body of knowledge indicates these negative balances of calcium, magnesium and phosph

signify the withdrawal of these elements from the skeleton, and since there was, in most cases at least, a superabundance of these nutrients in the rations in readily absorbable form it is apparent that the method of transfer of these nutrients from the bones to the mammary gland is such that the supplies present in the skeleton are more readily available, in part at least, than those directly absorbed from the alimentary tract, and that liberal milk production involves the withdrawal of calcium, magnesium and phosphorus from the skeleton in quantities somewhat greater than the skeleton is able to assimilate from the blood-stream, with the result that under these circumstances, without regard to the nitrogen metabolism, negative balances of calcium, magnesium and phosphorus must ordinarily prevail.

In this series of experiments there is some evidence of a relation between calcium intake and retention, but increased intake is not followed closely by increased storage—the irresponsiveness of cows to the increased calcium intake is especially prominent. This poor utilization of calcium was shown to be due not to lack of proper proportion between calcium, magnesium and phosphorus in the rations, nor to difficult solubility of the calcium compounds, nor to deficiency of common salt. The one pronounced case of deficient supply of calcium was in the timothy hay ration; otherwise very imperfect utilization associated with superabundant intake commonly prevailed.

Regarding the elimination of this group of elements from the body, calcium was present in the alkaline urine in exceedingly small quantities, but its amount was slightly increased where timothy hay was fed and the urine became acid.

Extremely little phosphorus also was usually present in the urine, though the amount was slightly increased by the timothy hay ration above referred to. Unlike calcium, however, phosphorus was sometimes much increased in the urine by general physiologic disturbance. A larger proportion of the outgoing phosphorus was contained in the milk and a smaller proportion occurred in the feces than was true in regard to calcium; that is, a larger proportion of the phosphorus than of the calcium of the rations was utilized.

Magnesium was always contained in the urine in greater quantities than calcium or phosphorus, but the feces contained much more magnesium than did the urine, sometimes two-and-a-half or three times as much; at other times, on other diets, nineteen times as much.

It thus appears that there is a marked difference in the responsiveness of milch cows to the intake of protein and energy-producing foods on the one hand and these mineral nutrients on the other. It may be that negative balances of calcium, magnesium and phosphorus are characteristic of the early part of the period of lactation without regard to the amount of milk produced, the inherited impulse of the cow to produce milk exceeding her capacity to assimilate the corresponding amounts of these materials, but it seems to us unlikely that this mineral overdraft occurs except as a result either of the selective intensification of the natural tendency of the cow to produce milk—the digestive and assimilative functions failing to meet the demands upon them—or in cases of actual mineral deficiency in the ration.

A fair question to ask in connection with this investigation is whether the whole plane of mineral intake was not so high as to render the negative balances without practical significance, in that they do not involve an approach to a critical state of mineral impoverishment, and that these losses might cease after a time, with the reestablishment of equilibrium on a lower plane of nutrient reserves. There are numerous instances in which we have suggested such an interpretation of negative balances, and in many cases it is impossible to say whether the facts should be so explained or not, but in regard to calcium, with its invariably negative balances, it seems to us that the case is more clear. In the timothy hay ration, containing no legumes, there is an actual deficiency of calcium; and in other rations with their much higher calcium contents we have an unexplained inefficiency of utilization.

That the negative calcium balances of the early part of the period of lactation become positive, after a time, when the milk-flow has become sufficiently reduced, is indicated by the work of Albert Anger.* Further evidence on this subject is needed, however, on account of certain unsatisfactory details of procedure in Anger's work, which render the results to a certain extent questionable.

The Balance of Mineral Acids to Bases in the Rations.—The balance of mineral acids to bases in the rations, as computed from their chemical analysis, always showed an excess of base except in the one case where timothy hay was the only roughage fed, and where the ration contained no feed of leguminous origin. Here, as has been previously remarked, the urine was acid. From this result we infer that in the absence of leguminous roughage the ration for the milch cow may be undesirably acid in character. The gene

*Anger, A., Ueber den Umsatz und Ansatz der Aschenbestandtheile, vornehmlich Kalk, Magnesia, Kali und Phosphorsaure, bei milch kühen, Inaug. Diss., Heidelburg, 1898

ailure of students of nutrition to recognize this possibility is due o overlooking the fact of the high silicon content, and the absorb- bility of certain silicon compounds of feeds, especially of roughages f the grass family.

INDEPENDENCE OF INDIVIDUAL MINERALS IN THEIR METABOLISM

Another point made clear by this investigation is the large neasure of independence which exists in the metabolism of the everal elements studied; thus calcium, magnesium and phosphorus, n account of their occurrence together in such quantities in the keleton, might be expected to be closely bound together in metab- lism, but in this investigation we found calcium and magnesium o an appreciable extent independent of each other, while phos- horus, by virtue of the considerable quantities contained in the oft parts, was sometimes retained during periods in which both alcium and magnesium were lost. The independence observed in ne metabolism of nitrogen and sulphur has already been remarked pon, as has also the general independence of the nitrogen and ineral metabolism.

The quantitative character of metabolism, therefore, appears o be highly variable; the body does not gain nor lose in each of s constituents at a definite proportional rate; rather, it exhibits surprising degree of metabolic adaptability. Under ordinary cir- umstances the nutrient reserves and physiologic safeguards con- itute an extensive field of compensation and adjustment between e organism and its environment, serving to protect from injurious cidents and to permit the enjoyment of benefits accruing from vorable circumstances, the ultimate dependence of the integrity metabolism upon each and every nutrient becoming fully mani- st only with the exhaustion of reserves and the overtaxing of hysiologic safety provisions.

DISCUSSION OF PRACTICAL BEARINGS

The chief interest of the practical agriculturist in such an vestigation as this one which we discuss is the bearing of the sults upon the business of dairy cattle management. The critical xperimenter realizes full well, however, that the drawing of such nclusions is the most difficult part of his task, for the reason that ter having studied a single factor among the many which compose e practical situation he is not in possession of evidence sufficient ally to warrant such conclusions as his constituency desires. The

environment of the animal is composed of such a complication
influences that it is impossible to determine the proportionate co
tribution of each of them, especially of the obscure and intrica
facts of mineral metabolism. Under these circumstances we ca
not do better than to call attention to our main findings, to outli
the general conditions as to related affairs in practice, and to mal
such suggestions in regard to dairy cattle management as seem
be useful and in harmony with the evidence, without implying
attempting to demonstrate a complete dependence of these su
gestions upon the evidence here adduced.

We have determined (1) that liberal milk production involv
a certain degree of impoverishment of the skeleton in mineral su
stance, (2) that rations which contain no leguminous roughage a
apt to be definitely lacking in mineral nutriment, especially calciu
(3) that the response of heavily-producing cows to liberal inta
of mineral nutriment is remarkable for its inefficiency, it bei
apparently impossible by any method of feeding entirely to preve
loss of calcium, at least during the early part of the period of lac
tion, and (4) that the mineral constituents of the skeleton app
to be more readily available for use in milk secretion than
nutrients directly absorbed from the ration.

It is true that most of these losses of minerals observed w
small, in comparison with the extent of the cow's mineral stor
and that these overdrafts may be restored, under favorable co
tions, during the latter part of the period of lactation when
milk-flow has fallen off to such extent that the withdrawal of m
erals from the skeleton is no longer required.

The practical significance of these losses is thought to lie in
fact that even though small they signify just so much decreas
the capacity of the animal to meet further like demands, and t
they may come to possess added significance during the unfavor
conditions which frequently exist in practice when the slight
observed under optimum conditions may become a larger one,
when the effects of any loss may be magnified by the critical c
acter of the animal's nutritional situation.

What should these facts mean to the dairy farmer? Le
consider certain general relations of the growth of animals to
mineral nutrients of their food.

The idea of the dependence of the skeletal development of
stock on the composition of the forage, and of the latter, in t
on the composition of the soil, is one which long ago became a
of the system of belief of thoughtful stock husbandmen; to

day, however, the subject has not been submitted to thoroughgoing experimental inquiry, though many fragments of evidence have been recorded, and an indefinite number of more or less scientific articles on the subject have appeared, especially in the agricultural press. We have not made a thorough review of the voluminous literature, but a considerable number of references may be found in our Review of the Literature of Phosphorus Compounds in Animal Metabolism (Technical Bulletin No. 5, Ohio Agricultural Experiment Station, pages 535 and 536).

One of the more interesting studies now in progress is that of Kisaku Kitta of the Imperial Livestock Experiment Station, at Chiba, Japan. This investigation is demonstrating marked differences in the composition of the grasses from two experimental farms, located on different types of soil, which differ in composition in significant ways; and the feeding to horses of the grasses grown upon these soils seems consistently to affect the skeletal development.

Similar observations have been made in Australia. Hilda Kincaid has found that the native vegetation of Victoria is characteristically poor in phosphorus. (Proc. Roy. Soc. Victoria, 23 (N. S.) Pt. II, 1911.) E. W. Murphy, also of Victoria, writes on the prevention of rickets, "cripples" and paralysis by the fertilization of pastures. According to Murphy these and related disorders are to be found in the livestock of Victoria, New South Wales, Tasmania and New Zealand. Milking cows and growing stock exhibit a comparatively high susceptibility. On the Mornington Peninsula, as the land was fenced and the range restricted, it was found impossible, in certain situations, to maintain cattle in good condition on the natural vegetation; after the improvement of the forage by fertilization with mineral and animal fertilizers, however, it became possible to maintain livestock in the best of condition (Journal Department of Agriculture, Victoria, XV, Part 8, August 10, 1917).

In our own country malnutrition of the bones of cattle is reported as occasionally though infrequently present in many regions; as quite prevalent in southern Alabama and also in some parts of Florida, Mississippi and the state of Washington.

In the Alabama situation the soil is sandy, and contains very little lime. The cattle referred to are on the ranges where legumes are present at all are scarce. As soon as these cattle are put on velvet beans and other farm crops, in the fall, they recover and come out in good condition. Here it is noticeable that cows are more commonly affected than are suckling calves, but the disorder is not entirely confined to the cows.

In the state of Washington this disorder is found in the western, rainy section, where the soils are reported to be very poor in lime.

This disorder has been found in a great variety of situations but most commonly in regions of infertile, sandy soils, or soils of granitic origin, especially if these be worn by long cropping, with insufficient fertilization. It may also be caused by close confinement and lack of roughage. Calves so treated have reached such a state of mineral impoverishment that the long bones of the leg have been fractured as the result of sudden fright.

The collection of evidence in this field is rendered difficult, and the results of uncertain value, by the confusion which exists as to the distinction between simple malnutrition of the bones, due to insufficient mineral intake, and the several diseases affecting the skeleton in which malnutrition of the bones may be a contributory cause. Clear-cut differentiation within this group of disorders awaits their further study.

The most familiar demonstration of the effects of the mineral draft of milk secretion on the natural organism is that furnished by the brood sow suckling a large litter of pigs while subsisting on a ration composed in the main of grain or grain products. Probably all experienced swine-herdsmen have seen sows "break down" under these conditions. This crippling is due in some cases to weakened tendinous attachments, but often to actual fracture of the leg bones.

Important factors in determining the susceptibility of the several kinds of farm animals to mineral starvation are (1) the extent of the mineral stores of the skeleton as determined by age, breed and species, (2) the rate and duration of milk production and (3) the mineral content of the ration.

In the literature we find several references to the prevalence of malnutrition of the bones following seasons of excessive heat and drouth. This condition bears some relation to the deficient mineral content of the forage, due to subnormal transpiration of mineral-bearing moisture from the soil. By laboratory studies we have found that there may be such an effect of limited water supply upon the mineral content of plants, but we do not find any general opinion among those best qualified to know that drouth leads directly to malnutrition of the bones.

We must not lose sight of the fact, however, in connection with the comparative rarity of acute malnutrition of the bones in cattle that our anxiety is not especially to feed in such manner as to prevent this malady, any more than our personal anxiety at all

time is to escape death by starvation; rather, it is our desire so to feed our animals, as well as ourselves, as to maintain a maximum state of efficiency, which in the one case is as far removed from malnutrition of the bones as in the other from general starvation.

Among other disorders of the nutrition of cattle which have been mentioned by our correspondents, in connection with the subject of mineral metabolism, but which have not been shown to relate directly to the results of this investigation are "alkali disease," reported from South Dakota and California, "Grand Traverse disease" from Michigan, and the hairlessness of the young at birth, reported as associated with goiter in Montana, Washington, Alaska and other states.

In an effort to gain an understanding of the bearings of the facts of mineral metabolism on the practical behavior of dairy cows we have carried on a systematic correspondence with professors of dairy husbandry and veterinary science. From this source we have reached a fair understanding of the prevailing intelligent opinion on this subject in this country, but it is well enough to understand that such inquiries are better calculated to raise questions than to settle them, and that no elaboration of criticism or treatment of mere records of opinion can give to such results the character of conclusions from fully controlled experimental investigations.

But however this may be, there is general agreement that sterility is common among milch cows, wherever large numbers of them are brought together in an intensive program of feeding, breeding and milk production, and that this failure to breed is becoming more prevalent. Much current opinion relates this situation to contagious abortion alone, but others, who are considered as competent to judge of the facts, are positive that a large proportion of the cases must be due to the operation of some other important and unexplained factor. It is reported, on the best of authority, that whole herds will fail to breed, during a limited period, apparently because of their state of nutrition, there being no indication of contagious abortion. At the same time there is a belief, so prevalent that we may regard its truth as established, that failure to breed is decidedly common, though by no means invariable, after especially heavy and protracted milk production, which, we have learned, calls for overdrafts at the mineral bank. It is also the prevailing opinion that failure to breed is more prevalent among dairy than among beef cows, and that the higher the dairy development of the cow the more frequently will there be difficulty in getting her to conceive. It is the prevailing belief

that this physiological disturbance is an effect of the combinatio of intensive milk production, heavy feeding, and the restraints o an unnatural environment; the delayed breeding of the heavy pro ducer, especially as handled in feeding for records of sustaine production, is thought also to be a factor.

It is also generally understood that gross overfeeding, ove allowance of protein, or any marked lack of balance in the ratio due to excessive proportion of certain feeds, even though they po sess great nutritive value, may cause abortion and temporary o permanent sterility; thus cottonseed meal, peanuts and velvet bean when used to excess, are believed to cause these disorders; and eve alfalfa, the very cream of forage plants, has been the cause of muc complaint, on the same score, when it is used to the practical excl sion of other feeds. The case against alfalfa has not been esta lished, but many men whose interests are involved consider th still a live problem. Of course this is quite without bearing on t normal use of alfalfa. No roughage has a greater general usefu ness. In its content of mineral nutriment it ranks at least amo the highest, and it has the reputation of producing large bone calves, colts and poultry.

It has been reported that dairymen who use slacked lime sweeten the mangers after feeding corn silage have less trou with sterility than do others who do not follow this practice.

It is also well known that the partial starvation which is caus by seasons of drouth, food shortage and other hardships is follow by increases of sterility and abortion. Any general injury of f age crops which results in loss of vitality in the cattle has li consequences.

That the composition of the forage and drinking water, related to the composition of the soil, has constituted an import factor in the evolution of the breeds of livestock is an idea advanc by Brown ("British Sheep Farming") in 1870. Brown's classifi tion of the ancient breeds of British sheep in relation to the geolo cal character of the soil was modified, elaborated and discussed length by McConnel in his "Elements of Agricultural Geolog McConnel classified these breeds of sheep into five groups, the g eral characters of which he believed had been determined by alluvial, chalk, limestone, sandstone and archaean (mountain) ty of soil upon which they had developed.

The character of wool as related to the soil upon which sheep were grown has also been remarked upon by Bakewell, and Youatt, and also by Rogers (Six Centuries of Work and Wag

From the results of this investigation, therefore, and in the ht of our general understanding of the subject of mineral metab- sm, we would offer the following recommendations to the dairy rmer, having in mind the provision of the full mineral require- nt of maintenance, growth, reproduction and milk secretion, and e protection of the cow, especially against the possibility (1) of minution of milk secretion, (2) of disturbance of reproduction,) of depletion of mineral reserves and (4) of malnutrition of the nes.

Get your farm into a high state of fertility, and treat the soil, necessary, so that it will grow legumes; then grow them, making liberal use as is profitable of fertilizers containing calcium and osphorus.

Consider with care your meadows and pastures; they are often glected; if the soil is not rich, the mineral nutrients in pasture ss may be doubled by fertilization.

Build up the mineral reserves of your cattle by growing them gely on leguminous roughage or on pastures containing an abun- ce of legumes; and allow them exercise, as much as they incline ake. Muscular activity increases the avidity of bone cells for eral salts.

Feed leguminous roughage during milk production; and give cow a chance to refund mineral overdrafts by continuing the ral feeding of leguminous roughage during the latter part of period of lactation, and during the dry period, before the birth he next calf.

Use as large a proportion of roughage in the ration as seems tical and profitable.

If you are short of leguminous roughage and must depend on fodder, straw, or hay made from grasses, or if on any other unt there is reason to believe that your cows are not receiving er bone food, give them bone flour. If they are already in good r there will be no marked change in condition, but the feeding one flour will help to keep them at their best, and is good ance.

We have not yet determined the best method of feeding bone . We have fed 2½ ounces per head per day mixed with the n, but it may be better, and all that is necessary, to allow cattle access to this preparation. This we hope to learn at an early

The results of this investigation, therefore, do not indicate t desirability of radical departure from those methods of dairy cat management which are practiced by the most successful dairym but they do illuminate the field in a way to add to our resour fulness in meeting the exigencies of practice by rational and c criminating modifications of procedure. Furthermore, the fa as we are finding them, contribute to the weight of evidence favor of good general agricultural practice.

TABLE I.—TOTAL FOODS CONSUMED AND MILK PRODUCED, AND LIVE WEIGHTS OF COWS—Grams.

Cow No. and days in period	Foods consumed									Milk produced	Weights of cows	
	Corn	Cotton-seed meal	Linseed oilmeal	Wheat bran	Alfalfa hay	Common salt	Precipitated bone flour	Calcium lactate	Calcium chloride		Average first five daily weights	Average last five daily weights
PERIOD I											*Kilos*	*Kilos*
1 20	99770	18140	18140	9070	145120	840.0	.....	.....	.....	461366	442.8	438.0
2 8	39738	7225	7225	3613	56860	334.8	.....	.....	.....	155113	416.0	.....
3 20	99770	18140	18140	9070	145120	840.0	.....	.....	.....	404884	489.9	486.3
4 20	99770	18140	18140	9070	145120	840.0	1400	.....	.....	416821	424.3	419.6
5 20	99770	18140	18140	9070	145120	840.0	1400	.....	.....	432844	422.2	422.5
6 20	99770	18140	18140	9070	145120	840.0	1400	.....	.....	425222	499.1	501.2
PERIOD II												
1 20	99770	18140	18140	9070	163280	840.0	.....	2225.040	.....	465229	444.8	451.3
2 10	37428	6805	6805	3403	72560	420.0	.....	556.260	.....	151419	.....	381.4
3 8	33672	6122	6122	3061	54199	304.5	.....	750.951	.....	148417	497.2	.....
4 16	79816	14512	14512	7256	130624	672.0	.....	.....	640.000	352026	422.4	424.5*
5 20	99770	18140	18140	9070	163280	840.0	.....	.....	800.000	453928	428.9	429.3
6 20	99770	18140	18140	9070	163280	840.0	.....	.....	800.000	441716	508.4	518.6

*Average of two weights only.

TABLE II—AVERAGE DAILY FOODS CONSUMED AND MILK PRODUCED—Grams.

Cow No. and days in period	Foods consumed									Milk produced
	Corn	Cottonseed meal	Linseed oilmeal	Wheat bran	Alfalfa hay	Common salt	Precipitated bone flour	Calcium lactate	Calcium chloride	
PERIOD I										
1 20	4989	907	907	454	7256	42	.....	.....	.....	23068
2 8	4967	903	903	452	7108	41.850	.....	.....	.....	19389
3 20	4989	907	907	454	7256	42	.....	.....	.....	20244
4 20	4989	907	907	454	7256	42	70	.....	.....	20841
5 20	4989	907	907	454	7256	42	70	.....	.....	21642
6 20	4989	907	907	454	7256	42	70	.....	.....	21261
PERIOD II										
1 20	4989	907	907	454	8164	42	.....	111.252	.....	23261
2 10	3743	681	681	340	7256	42	.....	55.626	.....	15142
3 8	4209	765	765	383	6775	38.063	.....	93.869	.....	18552
4 16	4989	907	907	454	8164	42	.....	.....	40	22002
5 20	4989	907	907	454	8164	42	.....	.....	40	22696
6 20	4989	907	907	454	8164	42	.....	.....	40	22086

TABLE III—COMPOSITION OF FOODS (Percent)

Food	Dry matter	Ether extract	Crude fiber	Nitrogen	Protein	Nitrogen-free extract	Ash	Sodium	Potassium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus	Silicon
Corn	86.19	4.27	1.51	1.384	8.65	70.54	1.22	0.001	0.313	0.009	0.107	0.093	0.032	0.245	0.014
Cottonseed meal	91.24	4.50	19.04	3.762	23.51	39.61	4.58	0.003	1.250	0.151	0.401	0.230	0.030	0.667	0.109
Linseed oilmeal	90.55	6.89	6.35	4.811	30.07	41.45	5.79	0.049	1.245	0.353	0.486	0.359	0.042	0.835	0.207
Wheat bran	89.54	4.19	7.49	2.380	14.88	61.12	1.86	0.039	1.583	0.103	0.587	0.173	0.065	1.574	0.023
Grain mixture (Per. II*)	89.14	4.80	4.10	2.444	15.28	62.25	2.71	0.024	0.663	0.082	0.230	0.186	0.030	0.482	0.052
Alfalfa hay (Per. I)	89.70	2.60	31.59	2.093	13.08	36.28	6.16	0.099	1.278	1.146	0.266	0.181	0.051	0.204	0.202
Alfalfa hay (Per. II)	91.46	2.58	27.45	2.562	16.02	35.94	9.48	0.039	3.018	1.225	0.156	0.260	0.319	0.241	0.444
Sodium chloride	.....	.....	.....	.....	.....	.....	.....	39.209	.....	.....	.....	.....	60.452	.....	.....
Precipitated bone flour	.....	0.15	.....	0.136	.....	.....	.....	0.259	.....	24.453	0.633	0.355	2.002	16.182	.....
Calcium lactate (Lot 2)	.....	.....	.....	0.191	.....	.....	.....	0.075	0.027	13.191	0.023	.....	0.245	.....	0.047
Calcium lactate (Lot 3)	.....	.....	.....	(0.050)	.....	.....	.....	(0.059)	(0.013)	13.293	.....	(0.020)	(0.085)	.....	0.178
Calcium lactate (Lot 4)	.....	.....	.....	(0.050)	.....	.....	.....	(0.059)	(0.013)	14.048	.....	(0.020)	(0.085)	.....	0.063
Calcium lactate (Lot 6)	.....	.....	.....	0.050	.....	.....	.....	0.059	0.013	14.249	.....	0.020	0.085	.....	0.087
Calcium chloride	.....	.....	.....	.....	.....	.....	.....	0.051	0.013	35.375	.....	.....	64.543	.....	.....

*This analysis represents all grains fed in Period II.

TABLE IV.—COMPOSITION OF MILK (Percent)

Cow No.	Moisture	Nitrogen	Protein (N x 6.37)	Ether extract	Ash	Sodium	Potassium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus
PERIOD I												
1	88.36	0.476	2.975	2.792	0.759	0.037	0.175	0.128	0.012	0.028	0.084	0.094
2	87.46	0.493	3.081	3.545	0.705	0.034	0.153	0.125	0.012	0.034	0.079	0.101
3	88.96	0.441	2.756	2.702	0.732	0.040	0.179	0.103	0.013	0.029	0.096	0.097
4	87.66	0.446	2.788	3.363	0.679	0.035	0.142	0.121	0.014	0.030	0.071	0.085
5	88.01	0.435	2.719	2.946	0.674	0.034	0.151	0.112	0.014	0.032	0.058	0.088
6	88.42	0.453	2.831	2.763	0.744	0.037	0.171	0.121	0.013	0.032	0.076	0.100
PERIOD II												
1	88.52	0.489	3.056	2.618	0.770	0.033	0.179	0.126	0.013	0.033	0.094	0.095
2	87.59	0.505	3.156	3.372	0.696	0.025	0.159	0.116	0.012	0.034	0.090	0.093
3	88.68	0.450	2.813	2.848	0.721	0.033	0.174	0.104	0.014	0.032	0.092	0.096
4	87.85	0.450	2.813	3.195	0.664	0.027	0.150	0.116	0.014	0.029	0.068	0.087
5	88.12	0.442	2.763	2.866	0.656	0.023	0.154	0.109	0.015	0.030	0.060	0.090
6	88.56	0.455	2.844	2.600	0.716	0.029	0.179	0.117	0.013	0.030	0.074	0.101

TABLE V.—CONSTITUENTS OF DAILY RATIONS (Grams)

Cow No.	Dry matter	Ether extract	Crude fiber	Nitrogen	Protein	Nitrogen free extract	Sodium	Potassium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus	Silicon
PERIOD I														
1	12864.72	524.02	2631.78	309.478	1934.16	7164.42	24.355	138.188	88.671	35.368	23.911	31.628	47.787	18.313
2	12704.80	518.74	2583.56	305.699	1910.55	7091.45	24.147	136.099	86.950	34.904	23.597	31.450	47.342	17.999
3	12864.72	524.02	2631.78	309.478	1934.16	7164.42	24.355	138.188	88.671	35.368	23.911	31.628	47.787	18.313
4	12864.83	524.13	2631.78	309.573	1934.16	7164.42	24.537	138.188	105.788	35.811	24.160	33.029	59.114	18.313
5	12864.83	524.13	2631.78	309.573	1934.16	7164.42	24.537	138.188	105.788	35.811	24.160	33.029	59.114	18.313
6	12864.83	524.13	2631.78	309.573	1934.16	7164.42	24.537	138.188	105.788	35.811	24.160	33.029	59.114	18.313
PERIOD II														
1	13936.35	558.92	2538.52	386.598	2416.59	7451.00	21.432	294.503	121.319	29.393	34.722	53.751	54.608	40.077
2	11490.37	448.51	2214.97	318.978	1994.25	5996.70	20.608	255.078	101.276	23.803	28.991	50.204	43.691	35.065
3	11654.87	468.66	2110.74	323.318	2020.80	6245.89	19.075	245.069	100.503	24.631	28.995	46.631	45.802	33.305
4	13936.35	558.92	2538.52	386.499	2416.59	7451.00	21.381	294.488	120.109	29.384	34.708	79.412	54.608	39.988
5	13936.35	558 92	2538.52	386.499	2416.59	7451.00	21.381	294.488	120.109	29.384	34.708	79.412	54.608	39.988
6	13936.35	558.92	2538.52	386.499	2416.59	7451.00	21.381	294.488	120.109	29.384	34.708	79.412	54.608	39.988

TABLE VI—CONSTITUENTS OF AVERAGE DAILY MILK (Grams.)

Cow No.	Nitrogen	Ether extract	Ash	Sodium	Potassium	Calcium	Magnesium	Sulphur	Phosphorus	Chlorine
PERIOD I										
1	109.804	644.059	175.040	8.512	40.369	29.504	2.860	6.436	21.776	19.308
2	95.588	687.340	136.654	6.650	29.665	24.198	2.385	6.670	19.525	15.356
3	89.276	546.993	148.166	7.996	36.237	20.770	2.713	5.790	19.677	19.394
4	92.906	700.547	141.338	7.208	29.580	25.185	2.937	6.208	17.665	14.748
5	94.143	637.573	145.759	7.358	32.679	24.153	3.116	6.839	19.067	12.617
6	96.312	587.441	158.097	7.909	36.356	25.662	2.658	6.718	21.155	16.201
PERIOD II										
1	113.746	608.973	178.993	7.746	41.637	29.332	3.117	7.583	22.005	21.819
2	76.467	510.588	105.373	3.725	24.076	17.489	1.772	5.163	14.021	13.567
3	83.484	528.361	133.834	6.122	32.280	19.331	2.616	5.844	17.810	17.105
4	99.009	702.964	146.137	5.831	33.003	25.522	2.992	6.313	19.054	14.961
5	100.316	650.467	148.954	5.220	34.952	24.829	3.336	6.854	20.426	13.618
6	100.491	574.236	158.025	6.361	39.534	25.885	2.849	6.560	22.263	16.255

TABLE VII.—CONSTITUENTS OF AVERAGE DAILY URINE (Grams)

Cow No.	Nitrogen	Sodium	Potassium	Calcium	Magnesism	Sulphur	Chlorine	Phosphorus
PERIOD I								
1	106.767	6.881	90.719	0.060	4.840	7.851	4.551	0.147
2	119.918	14.879	92.530	0.068	6.558	9.062	8.529	0.623
3	116.363	8.653	87.606	0.265	3.907	8.975	4.060	0.162
4	104.465	2.958	88.771	0.370	3.990	7.614	6.701	0.109
5	106.187	10.270	90.105	0.267	3.439	8.017	6.567	0.108
6	112.703	9.646	83.168	0.027	6.920	8.851	11.685	0.154
PERIOD II								
1	128.680	11.425	219.863	0.146	2.808	13.215	19.877	0.176
2	127.759	12.780	203.499	0.027	2.740	11.938	25.384	0.646
3	152.372	10.353	192.414	0.170	1.767	14.121	21.530	0.238
4	138.845	8.070	226.056	0.240	2.061	13.445	47.031	0.125
5	142.392	10.308	228.645	0.241	1.451	14.216	51.950	0.140
6	148.986	9.479	223.650	0.131	5.380	14.802	51.095	0.162

TABLE VIII.—CONSTITUENTS OF AVERAGE DAILY FECES (Grams)

Cow No.	Total weight	Dry matter	Ether extract	Crude fiber	Nitrogen	Protein	Nitrogen-free extract	Sodium	Potassium	Calcium	Mag-nesium	Sulphur	Chlorine	Phos-phorus
PERIOD I														
1	27,484	4 746.487	186.891	1,647.391	105.951	662.200	1,887.766	2.858	17.507	67.034	30.920	12.503	9.042	32.321
2	27 134	4,384.854	183.507	1,601.720	95.756	598.468	1,654.116	3.419	17.203	66.207	26.863	12.590	12.455	28.681
3	27 379	4 536.700	188.614	1,551.294	109.817	686.364	1,723.289	0.712	19.905	80.029	28.858	12.649	9.199	33.457
4	28 566	4,907.639	199.991	1,564.560	121.863	761.655	1,936.946	7.941	26.338	90.040	28.080	13.283	11.998	45.220
5	26 667	4,682.725	177.656	1,585.887	112.481	703.022	1,802.289	4.400	17.760	86.561	29.414	12.480	13.147	40.987
6	27,506	4 557 744	185.198	1,570.318	105.513	659.456	1,742.010	2.393	17.796	83.096	26.351	12.598	9.270	38.481
PERIOD II														
1	29 886	4 778.772	177.702	1,455.448	117.930	737.078	1,961.448	2.331	22.265	100.477	26.658	14.315	12.522	33.532
2	24 576	3 789.619	158.073	1,169.572	93.905	586.900	1,482.842	2.556	18.383	91.472	20.202	12.067	11.993	29.442
3	26 030	4 011.223	163.182	1 238.507	99.773	623.575	1,577.028	1.510	20.486	97.508	24.026	12.130	9.709	31.861
4	29 727	4,842.528	223.696	1 368.037	124.705	779.412	1 993.374	3.954	29.014	106.007	27.171	14.655	15.072	37.397
5	29 538	4 655.189	178.350	1.367.809	118.418	740.104	1 892.086	1.920	24.221	103.738	26.998	14.237	12.583	35.062
6	28 737	4 497.341	188.543	1 436.563	113.166	707.304	1 724.680	2.500	22.185	102.505	24.139	13.564	10.202	33.019

TABLE IX.—PERIOD I: AVERAGE DAILY RATIONS AND BALANCES OF MINERALS AND NITROGEN (Grams)

Cow No.	Average daily milk yield	Average daily ration	Distinguishing features of rations		Sodium	Potassium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus	Nitrogen
1	23,068	Corn, 4989; cottonseed meal, 907; linseed oil-meal, 907; wheat bran, 454; alfalfa hay, 7256; salt, 42	Basal ration	Food	24.355	138.188	88.671	35.368	23.911	31.628	47.787	309.478
				Milk	8.512	40.369	29.504	2.860	6.436	19.308	21.776	109.804
				Urine	6.881	90.719	0.060	4.840	7.851	4.551	0.147	106.767
				Feces	2.858	17.507	67.034	30.920	12.505	9.042	32.321	105.951
				Balance	+ 6.104	— 10.407	— 7.927	— 3.252	— 2.881	— 1.273	— 6.457	— 13.044
2	19,389	Corn, 4967; cottonseed meal, 903; linseed oil-meal, 903; wheat bran, 452; alfalfa hay, 7108; salt, 41.850	Basal ration	Food	24.147	136.099	86.950	34.904	23.597	31.450	47.342	305.699
				Milk	6.650	29.665	24.198	2.385	6.670	15.356	19.525	95.588
				Urine	14.879	92.530	0.068	6.558	9.062	8.529	0.623	119.918
				Feces	3.419	17.203	66.207	26.863	12.590	12.455	28.681	95.756
				Balance	— 0.801	— 3.299	— 3.523	— 0.902	— 4.725	— 4.890	— 1.487	— 5.563
3	20,244	Corn. 4989; cottonseed meal, 907; linseed oil-meal, 907; wheat bran, 454; alfalfa hay, 7256 salt, 42	Basal ration	Food	24.355	138.188	88.671	35.368	23.911	31.628	47.787	309.478
				Milk	7.996	36.237	20.770	2.713	5.790	19.394	19.677	89.276
				Urine	8.653	87.606	0.265	3.907	8.975	4.060	0.162	116.363
				Feces	0.712	19.905	80.029	28.858	12.649	9.199	33.457	109.817
				Balance	+ 6.994	— 5.560	—12.393	— 0.110	— 3.503	— 1.025	— 5.509	— 5.978
4	20,841	Corn, 4989; cottonseed meal, 907; linseed oil-meal, 907; wheat bran, 454; alfalfa hay, 7256; salt, 42; precipitated bone flour, 70	Basal ration plus precipitated bone flour	Food	24.537	138.188	105.788	35.811	24.160	33.029	59.114	309.573
				Milk	7.208	29.580	25.185	2.937	6.208	14.748	17.665	92.906
				Urine	2.958	88.771	0.370	3.990	7.614	6.701	0.109	104.465
				Feces	7.941	26.338	90.040	28.080	13.283	11.998	45.220	121.863
				Balance	+ 6.430	— 6.501	— 9.807	+ 0.804	— 2.945	— 0.418	— 3.880	— 9.661
5	21,642	Corn, 4989; cottonseed meal, 907; linseed oil-meal, 907; wheat bran, 454; alfalfa hay, 7256; salt, 42; precipitated bone flour, 70	Basal ration plus precipitated bone flour	Food	24.537	138.188	105.788	35.811	24.160	33.029	59.114	309.573
				Milk	7.358	32.679	•24.153	3.116	6.839	12.617	19.067	94.143
				Urine	10.270	90.105	0.267	3.439	8.017	6.567	0.108	106.187
				Feces	4.400	17.760	86.561	29.414	12.480	13.147	40.987	112.481
				Balance	+ 2.509	— 2.356	— 5.193	— 0.158	— 3.176	+ 0.698	— 1.048	— 3.238
6	21,261	Corn, 4989; cottonseed meal, 907; linseed oil-meal, 907; wheat bran, 454; alfalfa hay, 7256; salt 42; precipitated bone flour, 70	Basal ration plus precipitated bone flour	Food	24.537	138.188	105.788	35.811	24.160	33.029	59.114	309.573
				Milk	7.909	36.356	25.662	2.658	6.718	16.201	21.155	96.312
				Urine	9.646	83.168	0.027	6.920	8.851	11.685	0.154	112.703
				Feces	2.393	17.796	83.096	26.351	12.598	9.270	38.481	105.513
				Balance	+ 4.589	+ 0.868	— 2.997	— 0.118	— 4.007	— 4.127	— 0.676	— 4.955

TABLE X.—PERIOD II: AVERAGE DAILY RATIONS AND BALANCE OF MINERALS AND NITROGEN (Grams)

Cow No.	Average daily milk yield	Average daily ration	Distinguishing features of rations		Sodium	Potassium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus	Nitrogen
1	23,261	Corn 4989; cottonseed meal 907; linseed oil-meal 907; wheat bran 454; alfalfa hay 8164; salt 42; calcium lactate 11.252.	Basal ration plus calcium lactate	Food	21.432	294.503	121.319	29.393	34.722	53.751	54.608	386.598
				Milk	7.746	41.637	29.332	3.117	7.583	21.819	22.005	113.746
				Urine	11.425	219.863	0.146	2.808	13.215	19.877	0.176	128.680
				Feces	2.331	22.265	100.477	26.658	14.315	12.522	33.532	117.930
				Balance	—0.070	+10.738	— 8.636	— 3.190	—0.391	—0.467	— 1.105	+26.242
2	15,142	Corn 3743; cottonseed meal 681; linseed oilmeal 681; wheat bran 340; alfalfa hay 7256; salt 42; calcium lactate 55.626.	Basal ration plus calcium lactate	Food	20.608	255.078	101.276	23.804	28.991	50.204	43.691	318.978
				Milk	3.725	24.076	17.489	1.772	5.163	13.567	14.021	76.467
				Urine	12.780	203.499	0.027	2.740	11.938	25.384	0.646	127.759
				Feces	2.556	18.383	91.472	20.202	12.067	11.993	29.442	93.905
				Balance	+1.547	+ 9.120	— 7.712	— 0.910	—0.177	—0.740	— 0.418	+20.847
3	18,552	Corn 4209; cottonseed meal 765; linseed oilmeal 765· wheat bran 383; alfalfa hay 6775; salt 38.063; calcium lacate 93.869.	Basal ration plus oalcium lactate	Food	19.075	245.069	100.503	24.631	28.995	46.631	45.802	323.318
				Milk	6.122	32.280	19.331	2.616	5.844	17.105	17.810	83.484
				Urine	10.353	192.414	0.170	1.767	14.121	21.530	0.238	152.372
				Feces	1.510	20.486	97.508	24.026	12.130	9.709	31.861	99.773
				Balance	+1.090	— 0.111	—16.506	— 3.778	—3.100	—1.713	— 4.107	—12.311
4	22,002	Corn 4989; cottonseed meal 907; linseed oilmeal 907; wheat bran 454; alfalfa hay 8164; salt 42 calcium chloride 40	Basal ration plus calcium chloride	Food	21.381	294.488	120.109	29.384	34.708	79.412	54.608	386.499
				Milk	5.831	33.003	25.522	2.992	6.315	14.961	19.054	99.009
				Urine	8.070	226.056	0 240	2.061	13.445	47.031	0.125	138.845
				Feces	3.954	29.014	106.007	27.171	14.655	15.072	37.397	124.795
				Balance	+3.526	+ 6.415	—11.660	— 2.840	+0.293	+2.348	— 1.968	+23.940
5	22,696	Corn 4989; cotton seed meal 907; linseed oilmeal 907; wheat bran 454; alfalfa hay 8164; salt 42; calcium cloride 40	Basal rations plus calcium chloride	Food	21.381	294.488	120.109	29.384	34.708	79.412	54.608	386.499
				Milk	5.220	34.952	24.829	3.336	6.854	13.618	20.426	100.316
				Urine	10.308	228.645	0.241	1.451	14.216	51.950	0.140	142.392
				Feces	1.920	24.221	103.738	26.998	14.237	12.583	35.062	118.418
				Balance	+3.933	+ 6.670	— 8.699	— 2.401	—0.599	+1.261	— 1.020	+25.373
6	22,086	Corn 4989; cottonsed meal 907; linseed oilmeal 907; wheat bran 454; alfalfa hay 8164; salt 42; calcium chloride 40	Basal ration plus calcium chloride	Food	21.381	294.488	120.109	29.384	34.708	79.412	54.608	386.499
				Milk	6.361	39.534	25.885	2.849	6.560	16 255	22.263	100.491
				Urine	9.479	223.650	0.131	5.380	14.802	51.095	0.162	148.986
				Feces	2.500	22.185	102.505	24.139	13.564	10.202	33.019	113.166
				Balance	+3.041	+ 9.119	— 8.412	— 2.984	—0.218	+1.860	— 0.836	+23.856

TABLE XI—AVERAGE DAILY FEED, MILK AND BALANCE DATA FROM SIX COWS

Cow No.	Rations (Pounds)	Distinguishing features of ration	Milk yield	Gain or loss to the body (Grams)							
				Sodium	Potassium	Cacium	Magnesium	Sulphur	Clorine	Phosphorus	Nitrogen
				Intake Balance	Intake Balance	Intake Balance	Intake Balance	Intake Balance	Intake Balance	Intake Balance	Intake Balance
PERIOD I			*Lbs.*		138.188						
1	Corn 10.999; cottonseed meal 2.000; linseed oil meal 2.000; wheat bran 1.001; alfalfa hay 15.996; salt 0.9926	Basal ration	50.855	24.355 +6.104	— 10.407	38.671 —7.927	35.368 — 3.252	23.911 — 2.881	31.628 — 1.273	47.787 — 6.457	309.478 —13.044
					136.099						
2	Corn 10.950; cottonseed meal 1.991; linseed oilmeal 1.991; wheat bran 0.996; alfalfa hay 15.670; salt 0.0923		42.744	24.147 —0.801	— 3.299	86.950 — 3.523	34.904 — 0.902	23.597 — 4.725	31.450 — 4.890	47.342 — 1.487	305.699 — 5.563
					138.188						
3	Corn 10.999; cotton seed meal 2.000; linseed oilmeal 2.000; wheat bran 1.001; alfalfa hay 15.996; salt 0.0926		44.630	24.355 +6.994	— 5.560	88.671 —12.393	35.368 — 0.110	23.911 — 3.503	31.628 — 1.025	47.787 — 5.509	309.478 — 5.978
4	Corn 10.999; cottonseed meal 2.000; linseed oilmeal 2.000; wheat bran 1.001; alfalfa hay 15.996; salt 0.0926; precipitated bone flour 0.154	Basal ration plus precipitated bone flour	45.946	24.537 +6.430	138.188 — 6.501	105.788 — 9.807	35.811 + 0.804	24.160 —2.945	33.029 — 0.418	59.114 — 3.880	309.573 — 9.661
5	Corn 10.999; cottonseed meal 2.000; linseed oilmeal 2.000; wheat bran 1.001; alfalfa hay 15.996; salt 0.0926; precipitated bone flour 0.154		47.712	24.537 +2.509	138.188 — 2.356	105.788 — 5.193	35.811 — 0.158	24.160 — 3.176	33.029 + 0.698	59.114 — 1.048	309.573 — 3.238
6	Corn 10.999; cottonseed meal 2.000; linseed oilmeal 2.000; wheat bran 1.001; alfalfa hay 15.996; salt 0.0926; precipitated bone flour 0.154		46.872	24.537 +4.589	138.188 + 0.868	105.788 — 2.997	35.811 — 0.118	24.160 — 4.007	33.029 — 4.127	59.114 — 0.676	309.573 — 4.955

TABLE XI—AVERAGE DAILY FEED, MILK AND BALANCE DATA FROM SIX COWS—(Concluded)

Cow No.	Ration (Pounds)	Distinguishing features of rations	Milk yield	Gain or loss to the body (Grams)							
				Sodium	Potassium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus	Nitrogen
				Intake Balance	Intake Balance	Intake Balance	Intake Balance	Intake Balance	Intake Balance	Intake Balance	Intake Balance
PERIOD II			*Lbs.*								
1	Corn 10.999; cottonseed meal 2.000; linseed oilmeal 2.000; wheat bran 1.001; alfalfa hay 17.998; salt 0.0926; calcium lactate 0.245	Basal ration plus calcium lactate	51.281	21.432 − 0.070	294.503 − 10.738	121.319 − 8.636	29.393 − 3.190	34.722 − 0.391	53.751 − 0.467	54.608 −1.105	386.598 +26.242
2	Corn 8.252; cottonseed meal 1.501; linseed oilmeal 1.501; wheat bran 0.750; alfalfa hay 15.996; salt 0.0926; calcium lactate 0.123		33.382	20.608 + 1.547	255.078 + 9.120	101.276 − 7.712	23.804 − 0.910	28.991 − 0.177	50.204 − 0.740	43.691 −0.418	318.968 +20.847
3	Corn; 9.279; cottonseed meal 1.687; linseed oilmeal 1.687; wheat bran 0.844; alfalfa hay 14.936; salt 0.0839; calcium lactate 0.207		40.899	19.075 + 1.090	245.069 − 0.111	100.503 −16.506	24.631 − 3.778	28.995 − 3.100	46.631 − 1.713	45.802 −4.107	323.318 −12.311
4	Corn 10.999; cottonseed meal 2.000; linseed oilmeal 2.000; wheat bran 1.001; alfalfa hay 17.998; salt 0.0926; calcium chloride 0.0882	Basal ration plus calcium chloride	48.505	21.381 + 3.526	294.488 + 6.415	120.109 −11.660	29.384 − 2.840	34.708 + 0.293	79.412 + 2.348	54.608 −1.968	386.499 +23.940
5	Corn 10.999; cottonseed meal 2.000; linseed oilmeal 2.000; wheat bran 1.001; alfalfa hay 17.998; salt 0.0926; calcium chloride 0.0882		50.035	21.381 + 3.933	294.488 + 6.670	120.109 − 8.699	29.384 − 2.401	34.708 − 0.599	79.412 + 1.261	54.608 −1.020	386.499 +25.373
6	Corn 10.999; cottonseed meal 2.000; linseed oilmeal 2.000; wheat bran 1.001; alfalfa hay 17.998; salt 0.0926; calcium chloride 0.0882		48.690	21.381 + 3.041	294.488 + 9.119	120.109 − 8.412	29.384 − 2.984	34.708 − 0.218	79.412 + 1.860	54.608 −0.836	386.499 +23.856

TABLE XII.—MINERALS IN DAILY RATIONS COMPUTED TO NORMAL SOLUTIONS (Cubic centimeters)

Cow No.	Sodium	Potassium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus	Silicon	Total base	Total acid	Excess base
PERIOD I											
1	1,058.9	3,534.2	4,425.8	2,908.6	1,491.2	891.9	3,079.1	1,294.2	11,927.5	6,756.4	5,171.1
2	1,049.9	3,480.8	4,339.9	2,870.4	1,471.6	886.9	3,050.4	1,272.0	11,741.0	6,680.9	5,060.1
3	1,058.9	3,534.2	4,425.8	2,908.6	1,491.2	891.9	3,079.1	1,294.2	11,927.5	6,756.4	5,171.1
4	1,066.8	3,534.2	5,280.2	2,945.0	1,506.7	931.4	3,808.9	1,294.2	12,826.2	7,541.2	52,85.0
5	1,066.8	3,534.2	5,280.2	2,945.0	1,506.7	931.4	3,808.9	1,294.2	12,826.2	7,541.2	52,85.0
6	1,066.8	3,534.2	5,280.2	2,945.0	1,506.7	931.4	3,808.9	1,294.2	12,826.2	7,541.2	52,85.0
PERIOD II											
1	931.8	7,532.0	6,055.4	2,417.2	2,165.4	1,515.8	3,518.6	2,832.3	16,936.4	10,032.1	6,904.3
2	896.0	6,523.7	5,055.0	1,957.6	1,808.0	1,415.8	2,815.1	2,478.1	14,432.3	8,517.0	5,915.3
3	829.3	6,267.7	5,016.4	2,025.6	1,808.2	1,315.0	2,951.2	2,353.7	14,139.0	8,428.1	5,710.9
4	929.6	7,531.6	5,995.0	2,416.4	2,164.5	2,239.5	3,518.6	2,826.0	16,872.6	10,748.6	6,124.0
5	929.6	7,531.6	5,995.0	2,416.4	2,164.5	2,239.5	3,518.6	2,826.0	16,872.6	10,748.6	61,24.0
6	929.6	7,531.6	5,995.0	2,416.4	2,164.5	2,239.5	3,518.6	2,826.0	16.872.6	10 748.6	61,24.0

TABLE XIII.—UTILIZATION AND ELIMINATION OF NITROGEN

Cow No.	Distinguishing features of rations	Nitrogen in rations per day	Nitrogen in urine per day	Nitrogen of food in urine	Utilization of nitrogen	Nitrogen of food in feces
PERIOD I		*Grams*	*Grams*	*Percent*	*Percent*	*Percent*
1	Basal ration	309.478	106.767	34.499	31.266	34.24
2		305.699	119.918	39.227	29.449	31.32
3		309.478	116.363	37.600	26.916	35.49
4	Basal ration plus precipitated bone flour	309.573	104.465	33.745	26.890	39.38
5		309.573	106.187	34.301	29.365	36.35
6		309.573	112.703	36.406	29.511	34.10
PERIOD II						
1	Basal ration plus calcium lactate	386.598	128.680	33.285	36.210	30.50
2		318.978	127.759	40.053	30.508	29.43
3		323.318	152.372	47.128	22.013	30.86
4	Basal ration plus calcium chloride	386.499	138.845	35.924	31.811	32.25
5		386.499	142.392	36.841	32.520	30.63
6		386.499	148.986	38.548	32.173	29.27

TABLE XIV.—COEFFICIENTS OF DIGESTIBILITY OF RATIONS

Cow No.	Distinguishing features of rations	Protein	Nitrogen-free extract	Ether extract	Crude fiber	Nutritive ratio of rations
PERIOD I						
1	Basal ration	65.76	73.65	64.34	37.40	1 : 5.52
2		68.68	76.67	64.62	38.00	1 : 5.46
3		64.51	75.95	64.01	41.06	1 : 5.83
4	Basal ration plus precipitated bone flour	60.62	72.96	61.84	40.55	1 : 5.99
5		63.65	74.84	66.10	39.74	1 : 5.84
6		65.90	75.69	64.67	40.33	1 : 5.68
PERIOD II						
1	Basal ration plus calcium lactate	69.50	73.68	68.21	42.67	1 : 4.46
2		70.57	75.27	64.76	47.20	1 : 4.44
3		69.14	74.75	65.18	41.32	1 : 4.49
4	Basal ration plus calcium chloride	67.75	73.25	59.98	46.11	1 : 4.54
5		69.37	74.61	68.09	45.37	1 : 4.55
6		70.73	76.85	66.27	43.41	1 : 4.51

TABLE XV.—PERIOD I: DISTRIBUTION OF OUTGO OF ELEMENTS AMONG MILK, URINE AND FECES (Percent)

Cow No.	Rations	Sodium	Potassium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus	Nitrogen
		Milk Urine Feces	Milk Urine Feces	Milk Urine Feces	Milk Urine Feces	Milk Urine Feces	Milk Urine Feces	Milk Urine Feces	Milk Urine Feces
1	Corn; cottonseed meal; linseed oilmeal; wheat bran; alfalfa hay; salt	46.64 37.70 15.66	27.17 61.05 11.78	30.54 0.06 69.40	7.41 12.53 80.06	24.02 29.30 46.68	58.69 13.83 27.48	40.15 0.27 59.58	34.05 33.10 32.85
2	Corn; cottonseed meal; linseed oilmeal; wheat bran; alfalfa hay; salt	26.66 59.63 13.71	21.28 66.38 12.34	26.47 0.08 73.18	6.66 18.32 75.02	23.55 32.00 44.45	42.26 23.47 34.27	39.98 1.28 58.74	30.71 38.53 30.76
3	Corn; cottonseed meal; linseed oilmeal; wheat bran; alfalfa hay; salt	46.06 49.84 4.10	25.21 60.94 13.85	20.55 0.26 79.19	7.65 11.01 81.34	21.12 32.74 46.14	59.40 12.43 28.17	36.92 0.30 62.78	28.30 36.89 34.81
4	Corn; cottonseed meal; linseed oilmeal; wheat bran; alfalfa hay; salt; precipitated bone flour	39.81 16.34 43.85	20.45 61.35 18.20	21.79 0.32 77.89	8.39 11.40 80.21	22.90 28.09 49.01	44.09 20.04 35.87	28.04 0.17 71.79	29.10 32.72 38.18
5	Corn; cottonseed meal; linseed oilmeal; wheat bran; alfalfa hay; salt; precipitated bone flour	33.40 46.62 19.98	23.25 64.11 12.64	21.76 0.24 78.00	8.66 9.56 81.78	25.02 29.33 45.65	39.03 20.31 40.66	31.69 0.18 68.13	30.09 33.95 35.96
6	Corn; cottonseed meal; linseed oilmeal; wheat bran; alfalfa hay; salt; precipitated bone flour	39.65 48.35 12.00	26.48 60.56 12.96	23.58 0.03 76.39	7.40 19.26 73.34	23.85 31.42 44.73	43.60 31.45 24.95	35.38 0.26 64.36	30.62 35.83 33.55

TABLE XVI.—PERIOD II: DISTRIBUTION OF OUTGO OF ELEMENTS AMONG MILK, URINE AND FECES (Percent)

Cow No.	Rations	Sodium	Potassium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus	Nitrogen
		Milk Urine Feces	Milk Urine Feces	Milk Urine Feces	Milk Urine Feces	Milk Urine Feces	Milk Urine Feces	Milk Urine Feces	Milk Urine Feces
1	Corn; cottonseed meal; linseed oilmeal; wheat bran; alfalfa hay; salt; calcium lactate	36.03 53.13 10.84	14.67 77.48 7.85	22.57 0.11 77.32	9.57 8.62 81.81	21.60 37.63 40.77	40.24 36.66 23.10	39.50 0.31 60.19	31.56 35.71 32.73
2	Corn; cottonseed meal; linseed oilmeal; wheat bran; alfalfa hay; salt; calcium lactate	19.54 67.05 13.41	9.79 82.74 7.47	16.05 0.02 83.93	7.17 11.09 81.74	17.70 40.93 41.37	26.63 49.83 23.54	31.79 1.46 65.75	25.65 42.85 31.50
3	Corn; cottonseed meal; linseed oilmeal; wheat bran; alfalfa hay; salt; calcium lactate	34.04 57.56 8.40	13.16 78.48 8.36	16.52 0.15 83.33	9.21 6.22 84.57	18.21 44.00 37.79	35.38 44.54 20.08	35.68 0.48 63.84	24.87 45.40 29.73
4	Corn; cottonseed meal; linseed oilmeal; wheat bran; alfalfa hay; salt; calcium chloride	32.66 45.20 22.14	11.46 78.47 10.07	19.37 0.18 80.45	9.28 6.40 84.32	18.35 39.07 42.58	19.41 61.03 19.56	33.68 0.22 66.10	27.31 38.30 34.39
5	Corn; cottonseed meal; linseed oilmeal; wheat bran; alfalfa hay; salt; calcium chlorde	29.92 59.08 11.00	12.14 79.44 8.42	19.27 0.19 80.54	10.50 4.56 84.94	19.41 40.26 40.33	17.43 66.47 16.10	36.72 0.25 63.03	27.78 39.43 32.79
6	Corn; cottonseed meal; linseed oilmeal; wheat bran; alfalfa hay; salt; calcium chloride	34.68 51.69 13.63	13.85 78.37 7.78	20.14 0.10 79.76	8.80 16.62 74.58	18.78 42.38 38.84	20.96 65.88 13.16	40.16 0.29 59.55	27.71 41.08 31.21

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